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A History Update of the U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Virginia 1984-1988

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Preface

There are two obstacles one faces in doing a history of the U.S. Army Engineer Topographic Laboratories (USAETL): daunting complexity and sheer volume. There is a lot of material, and most of it makes little or no immediate sense to the nontechnical professional.

Technical language is the first hurdle. So much of what USAETL scientists write and do is recounted in reports that make sense to them, but not necessarily to us. This is not the result of any creeping illiteracy at Fort Belvoir, Va. It is, rather, the result of several technical vocabularies being in use at the same time, in the same place, and not one of them renders itself into everyday English easily. The very same cross-fertilization that is so vital to the laboratories' success can easily turn this history into a technical Tower of Babel.

Accordingly, every effort has been made in this history to reduce the tech talk to the lowest common denominator (i.e., you and me), even if some fine lines get blurred a bit in the process. A mapmaker might find that unforgivable, but it is really the only way for the novice to begin to follow what USAETL was doing.

Then, apart from the tech talk, there is the sheer volume of information that deals with USAETL in the years 1984-1988. Actually, it is somewhat like making a map. First, you must harvest large amounts of information and then you must sift and winnow it, reducing all this information into a map.

But, as spending time around the laboratories' cartographers would convince you in a hurry, making maps is harder than you ever imagined. Indeed, in trying over the years to program computers to make maps, USAETL's specialists have found mapmaking to be even harder than *they* imagined. Yet, any history of the laboratories must, in a similar fashion, gather and interpret a wealth of material. Then, much like the cartographer, the historian must decide what to keep on and what to leave off the page. For just as a map with too much information is "too busy" to read easily, a history that recounts everything is just collected information, not history. And as Jacques Barzun said: "if you underline *everything* in a story, you underline *nothing*."

This history does not underline everything; indeed, it makes no pretense of providing a systematic technical understanding of the work it discusses. It avoids doing this for three reasons: (1) understanding such a variety of projects is well beyond the author's ability, but (fortunately for him), (2) that is not what a history is supposed to do. Finally, (3) the technical background to the laboratories' projects is readily available in USAETL's own excellent *Tech-Tran*, a quarterly information technology transfer bulletin, its periodic *Organizational Activities* summary, and its published technical reports.

By contrast, this history tells what generally happened but can never presume to recount how everything worked that caused it. In this history, we can only hope to get a general understanding of what was going on at USAETL during a 5-year period.

In the previous history of the 1979-1983 period at USAETL, the authors expressed some doubt that even the great philosopher and scientist Leibnitz, the "last man to know everything," could understand everything going on in the laboratories. For the 1984-1988 period, with the facility having grown in every way, there is no doubt at all, Leibnitz would have needed a lot of help.

Dr. Robert Hellman

Mr. Walter E. Boge was Director, and Lt. Col. Louis R. DeSanzo was Commander and Deputy Director of the Topographic Engineering Center at the time of publication of this report.

Acknowledgments

The author wishes to thank USAETL scientists and researchers for their help, freely given. Special thanks to Douglas Caldwell, Daniel Edwards, George Simcox, Laslo Greczy, Dr. Jack N. Rinker, Theodore Howard, Frank Capece, John Benton, William Clark and Col. David F. Maune. Thanks also to Darlene Seyler and the entire Liaison Office team for their help and patience.

Finally, this history made liberal use of summary accounts found in *Tech-Tran* and other USAETL publications. Much of the merit of this material is not only found in the submissions of the project bosses but also in the lucid renderings of Mark Ross and Jackie Bryant, along with the useful graphics of Barbara Jayne. Those three individuals also were equally helpful in directing the author to the right person, at the right place, at the right time — no mean feat at USAETL.

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Introduction and Overview:

1984-88 - Years of change and growth at USAETL

As with any big, complex project, it is necessary to construct a general framework. Within USAETL, there are so many projects and so many approaches taken to solving problems that a general overview of the 1984-1988 years must precede the individual summaries of major initiatives. In this way, it is possible to show the general direction of change. Broad changes in emphasis and the reorganizations do not come into proper focus by following every detail of research projects, studies, and development systems. Quite simply, there are too many of them. These were, after all, growth years at USAETL. Consider the funding profile:

1984: $52.8m
1985: $49.7m
1986: $81.m
1987: $90.6m
1988: $104.5m

It bears emphasizing that this expansion took place during a period of general decline in research and development funding elsewhere in the military. [*Army Research and Development Organization of the Year Report for FY88,* page 2.[1]] A glance at USAETL's organizational charts for these growth years makes it clear that many changes occurred. The change in the work load was reflected, not only in the construction of a 5,000-square-foot annex, but in the fact that the laboratories were totally reorganized. The annex increased the laboratories' size, while the reorganization was a long overdue response to USAETL's growth and shifting of focus.

Growth in hard times, of course, testified to the fact that USAETL's customers "were extremely pleased with the results obtained or else such growth would never have occurred . . ." [Interview with Col. David F. Maune, Fort Belvoir, Va., 4 November 1991.[2]]

Transformation at USAETL

As part of the transformation in the 1984-1988 time frame, pioneer researchers Dr. Kenneth Kothe, Robert Frost, Dr. Robert Leighty, and John Armistead retired or neared retirement; the Terrain Analysis Center (TAC) increased in size; and a division was specifically created to manage Digital Topographic Data requirements. It can be no surprise that a new addition had to be added to the Cude Building to handle some of this new activity.

With these changes came a tremendous increase in USAETL's operational mission. Much, but not all, of this can be attributed to TAC. There was, however, an overall focus of providing the Army with a bridge to the terrain support that the Defense Mapping Agency's (DMA) standard products could not provide. To that end, a host of new approaches and technologies were undertaken.

It would be a mistake, however, to underestimate continuity in the laboratories' research. Some problems were abiding, and research to solve them was ongoing. Some solutions proved hard, even impossible, to identify with contemporary technology. For example, storage and transmission of vast amounts of digital data remained a problem, as did some other technologies such as automating cartography to speed up the mapmaking process. First among these problems, going back to World War II, was the need to streamline the process of making maps. Though USAETL had long moved on to addressing the wider concern of terrain information, there was still a backlog of demand for up-to-date maps.

Mapmaking process

First, there is the mapmaking process itself, involving the laborious gathering of information and the equally laborious process of turning this information into a comprehensible map. The latter step requires, in turn, some expert judgment as to what is included and excluded. The skill, to say nothing of the patience, required in these steps is always an eye-opener to those of us who have long taken maps for granted. It was an abiding bottleneck in the period 1979-1983 and it remained one in the years 1984-1988. The trend, said Col. Maune, was toward "computer-assisted photo interpretation" and determining "what was best done by a human and what was best done by a machine." [Interview with Col. David F. Maune, Fort Belvoir, Va., 4 November 1991.[3]]

While improvements had been made, and certain technological shortcuts found, all problems had not been solved, despite a dramatic turn from traditional paper maps to digital ones.

Automated mapmaking

But even with the automated mapmaking process essentially unsolved, one could argue that the turn from paper maps and the problems of paper mapmaking marked a turning point in the history of USAETL in this 1984-1988 period. Artificial Intelligence specialist Anne Werkheiser might have seen the change in terms of a turn toward "visualization," while George Lukes, working on Computer Image Generation with Laslo Greczy, spoke of having an "electronic sand table." Daniel Edwards felt imagery itself could be a possible solution, while Michael McDonnell honed his software to supplant contour maps with perspective image displays. They were all addressing aspects of the same problem: how to make the best use of whatever information we *do* have, whether it was gathered from aerial photography, existing maps, or even out of an old desk drawer. It was, as Douglas Caldwell put it, "a new focus on the *product.*"

Work on automated mapping technology continued. Richard Marth said, "paper maps were just as hard to make as things that work much better," and besides, he added, "*maps are flat!*" Maps were hard to read, and they were bulky. More than that, they were not suited to the magical manipulations that could be worked out on computer screens. And they were still proving just as hard to make as the digital terrain product that stood to replace them.

Perhaps the key was that, as Col. Maune observed, digital maps, when rendered in "vector" (as opposed to "raster") form, may have looked like "colored spaghetti" to a human, but not to a computer. A computer, he noted, "could plough through such data and come up with a terrain analysis product." [Interview with Col. David F. Maune, Fort Belvoir, Va., 4 November 1991.[4]]

Force multiplier for the military

With mapmaking for the military, producing such a terrain analysis product takes on an added dimension. Typically, the military user operates in great urgency, and with a need for more precision and accuracy. Getting terrain information to the commander in the field is what the Army tacticians call a "force multiplier," helping to make every bit of firepower count and minimizing losses for the new, highly mobile Army.

Having up-to-date, precise, terrain information is no mere convenience, nor is it even just a tactical plus; the whole direction of research and development at USAETL in the years 1984-1988 clearly demonstrates that knowledge of the terrain and precise location had become critical factors in modern "shoot and scoot" warfare.

DTSS finds new users

The need for accurate knowledge of the terrain led USAETL into the development of the Digital Topographic Support System (DTSS). William Clark's team labored to sell the digital system as a boon to terrain teams and engineers, offering potential support to the All-Source Analysis System (ASAS). By the end of the 1984-1988 period, the DTSS and related technology had rapidly gained the attention of the intelligence elements, command and control, and even the air defense and maneuver people. [Interview with Laslo Greczy, Fort Belvoir, Va., 16 January 1992.[5]] Like so many projects at USAETL, DTSS had evolved in unforeseen and spectacular ways.

Advances in map reproduction

Despite finding a host of new users for DTSS, Geographic Sciences Laboratory (GSL) researchers, along with others at USAETL, pressed on with solutions to aspects of the old mapmaking bottleneck problem, map reproduction. In this area USAETL scientists continued work on a new map reproduction technology they envisioned as the "first significant advance in combat map reproduction since World War II," the Quick Response Multicolor Printer (QRMP). [USAETL in-house QRMP brochure, unpaginated.[6]] This was a significant advance, but again, by this period, the unmistakable tendency was to refine ways of using digital maps. Even the QRMP was to have a digital interface.

Focus on the product

But if the QRMP could reproduce the product, from digital input or hard copy, what kind of product should that be? GSL cartographer Caldwell made a chart to show how terrain information could be used. This chart, simplified here, recognizes a basic dilemma: that producing a sophisticated terrain analysis product takes time and, thus, the product may not be up-to-date.

- **Photos** - Most current, but least informative.
- **Maps** - Less current, but more informative.
- **Terrain Analysis Products** - Least current, but most informative.

This simplified scale is discussed at greater length in the chapter on GSL. The scale is useful to the layman; we clearly see that the optimal product in one sense may not be at all optimal in another.

Of what use is the most current aerial photo (the most

current product) if it does not contain the required information or is unintelligible to the field commander? On the other hand, of what use is the most sophisticated terrain analysis product (e.g., a simulated fly-through software capability), even if it has the most information, if it is out-of-date? USAETL sought to find answers to these questions through digital technology research.

General orientation of research

Complicated as USAETL's work is, it is nonetheless possible to outline the general directions of USAETL's work in the period 1984-1988. In later chapters there will be an individual and more detailed breakdown of the primary work undertaken on the most significant fronts, though even those more detailed studies cannot begin to provide more than a quick glance at what was going on.

Generally, USAETL's quest was for real-time knowledge of the terrain, to be captured, in turn, from:

1. Imagery (feature extraction, battlefield geometry)
2. Computer Image Generation (feature presentation)
3. Display Technology (graphic rendition)
4. Automated Terrain Analysis (data manipulation)
5. Autonomous Vehicle Control (terrain analysis for robotic systems)
6. Automated Targeting (image analysis and point positioning)

New technologies and Army demands for digital data shunted aside several traditional customers and historically significant activities: various automated cartography studies, the Autonomous Land Vehicle (ALV), and a number of projects undertaken for DMA. On the other hand, new projects were created, there was more work for the Army Space Program Office (ASPO), and there was a new element for managing the demand for DTD.

Throughout these changes, many of the traditional avenues of research — new survey technologies, ways to lighten DMA's burden, investigations related to digital manipulation, remote sensing advances — remained important, and many long-standing struggles continued.

Acquisition struggle continues

No overview of the 1984-1988 years would be complete without some mention of USAETL's continuing battle for attention between technologies that look to the future and technologies that look to the needs of the present. Caldwell called this the "struggle between 'Life Cycle' and 'End Run' approaches," between technologies developed from the ground up, generally for the long-term, and technologies using off-the-shelf equipment. Often, but not always, this also involved deciding between that which was somewhat uncertain, but potentially ideal, and that which was fairly certain, but less ideal: the final solution later versus a quick fix now.

It goes back, in a sense, to the earlier terrain data chart, where the ideal product (Terrain Analysis Product) suffered for lack of being up-to-date. But here the ideal, wholly preplanned technology (life cycle) suffers from being cut off from the most current developments. The end-run product, in turn, incurs the risk of being poorly supported when it comes on-line.

TAC and CAD mark operational turn for USAETL

The swift growth of TAC in these years gave some new importance to end-run solutions, through the very nature of TAC's "help right now" operational mission. Even the formation of the Concepts and Analysis Division (CAD, later the Digital Concepts and Analysis Center (DCAC)) in 1986, showed a determination to bring some of the Army's high-tech digital data demands down-to-earth while providing what could be provided now.

Before one concludes, however, that USAETL lost all of its "laboratory" or R&D character and came down wholly on the side of the end-run approach, it should be noted that a great deal of abstract work continued. The Research Institute (RI) pursued its Artificial Intelligence (AI), remote sensing imagery and autonomous land navigation research. GSL looked into terrain data generation and visualization, and the new (1986) Space Programs Laboratory (SPL) did some classified work on some highly futuristic ASPO initiatives.

Indeed, even TAC and CAD were hardly dealing with stopgap solutions. While CAD was providing analytical support and technical advice to dozens of Army materiel and combat developers, TAC was automating and employing state-of-the-art software where it could, especially in support of its terrain data base.

Unique facility

In the broadest sense, however, there is no mistaking the trend at USAETL in the years 1984-1988. USAETL's major operation and maintenance mission had grown. More than ever, it was a unique laboratory in that it "bent metal" and fielded and maintained operational systems. Col. Maune had good reason to cite the "unique" nature of USAETL's role. [*Army Research and Development Organization of the Year Report for FY88*, page 1.[7]]

But this uniqueness, allowing for cross-fertilization between researchers and users, required a better organizational structure than that with which USAETL

entered the 1984-1988 period. USAETL was, after all, not only doing new things, but *more* things in these years.

Reorganization in 1986

USAETL's growth and evolution in the years 1984-1988 made reorganization a necessity. Some projects in these years were successfully completed and led to fielding, while others were overtaken by better solutions. Nevertheless, the shift in people, customers and priorities was so major that it all pointed to a revolution in the way things were being done at the laboratories.

Real changes underway

The institutional changes in this time frame signified much more than moving desks and new name plates. In 1985, and again in 1988, for example, TAC was re-reorganized to reflect its growth and added responsibilities; and, equally important, CAD was established in 1986 to try to manage the Army's "exploding appetite" for DTD. [Briefing by Richard Herrmann, Fort Belvoir, Va., 11 January 1990.[8]] Finally, when USAETL Commander and Director Col. Alan L. Laubscher directed a ground-up reorganization of USAETL, former Commander and Director Col. Edward K. Wintz wrote to emphasize the historical grounds for it:

"Given the fact that we didn't have a realignment for many years despite drastic changes in customers and funding, one certainly seems due." [Letter in *Lab Lines*, September/October 1986.[9]]

Col. Laubscher's decision to reorganize had not been made lightly. It meant a lot of rethinking, some hard guessing about the future, and some inconvenient relocation of long entrenched personnel. He took on the heavy responsibility with good humor, however (as the *Lab Lines* of the period demonstrates), and the die was cast.

Response to a "Digital Topographic Revolution"

Col. Laubscher thought these changes so dramatic that he called them a manifestation of a "Digital Topographic Revolution" that he saw resulting from the Army's "renewed interest in topographic support" which emerged during an evening visit by Gen. Maxwell Thurman, the Army Vice Chief of Staff. Indeed, perhaps the clearest expression of that renewed interest was his finding himself faced with a "string of VIP visits and briefings" in 1986, following the vice chief of staff visit that "seem almost endless." [An Open Letter to former Commander and Director Col. Edward K. Wintz (Ret.), *Lab Lines*, September/October 1986, page 2.[10]] He observed that "new missions and roles for USAETL seem to be arising almost daily," but counted himself fortunate to be in command during "exciting times" for the laboratories. [Ibid.[11]]

The changes colonels Wintz and Laubscher alluded to were largely a result of the many new systems arising that required digital topographic/terrain/environmental data, many of which are discussed in detail elsewhere in this history. The third commander in this period, Col. Maune, would create a *Digital Data Digest* newsletter to keep abreast of the revolution. But here it suffices to say that the laboratories needed to reorganize in 1986 to be better suited to handle these new missions.

Visit from Gen. Thurman

Col. Maune later would cite the Thurman visit as "pivotal." Gen. Thurman had used that occasion to outline the problem and to direct USAETL to become an Army center of topographic expertise to manage the growing digital data requirements of the Army. Such a task could not have been accomplished effectively under the old organization, many of whose branch and division titles still reflected long-abandoned research.

Shortly thereafter, the laboratories' top management met in an "off site" for several days to hammer out a new organizational structure. Keeping its customers in mind, the team delineated functional areas and then developed long-range plans for each. It was immediately obvious that the current organizational structure, a holdover from 1972 had outlived its usefulness and no longer reflected the direction of research or the needs of the potential users.

A major recasting was clearly needed. The leaders of USAETL decided they would not only have to create new branches and divisions, but also move personnel to different projects as well.

New divisions and relocated personnel

Changes were major! In creating CAD alone, 13 senior personnel had to be redirected from the technology base program to the new division. Similarly, in response to the Corps' director of Research and Development making USAETL the Corps' R&D Executive Agent for Space, all laboratory space efforts, including those in support of ASPO, were placed in SPL (formerly the Computer Sciences Laboratory).

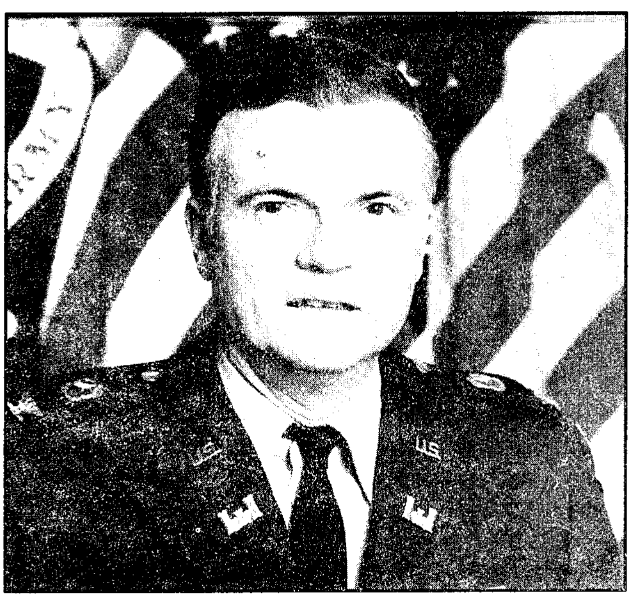
In another function-related name change, the Geographic Sciences Laboratory briefly became the Geographic Systems Laboratory, and "GSL" now had a new division to manage DTSS and QRMP. Later, this would be changed back to Sciences, to better reflect where the real hardware systems were being developed

and by whom. Another division was recast to better focus USAETL's Terrain Analyst Work Station (TAWS) input into the AirLand Battlefield Environment program, and that change would stick.

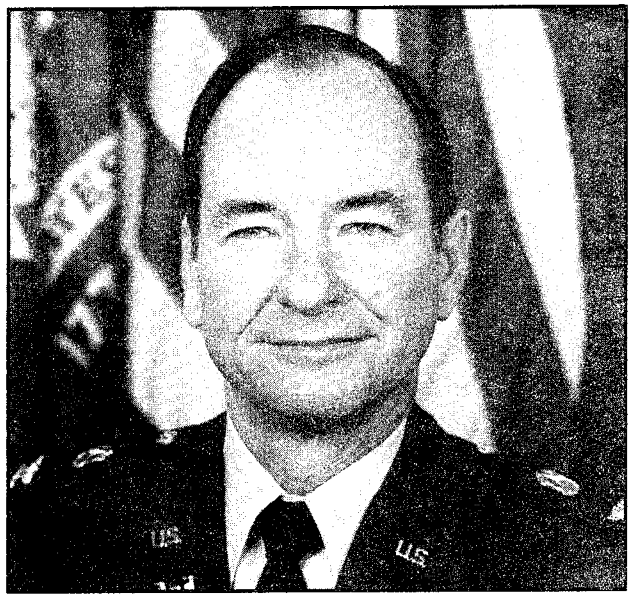
Meanwhile, at RI, the new Center for Autonomous Technologies consolidated the laboratories' work in that area, including the ALV program and related Army programs. To that end, a branch of GSL was transferred to RI to form the center. Dr. Leighty sought to integrate some GSL Computer-Assisted Photo Interpretation (CAPIR) technology into ALV, but in time ALV would largely leave USAETL. In general, however, the focus of research continued on extracting data from remotely sensed imagery, motion detection, route planning using expert systems, new techniques of "visualization," and exploiting promising new scanning techniques.

Finally, a new Information Management Office took over a number of staff functions, including publication of reports and managing information systems. So thorough was the reorganization that only TAC was unaffected, and that was only because TAC already had been reorganized in 1982 and 1985. Even so, TAC also gained new responsibilities, supporting Army requirements for nonstandard format DTD by means of a data transformation and data enrichment capability.

It was, in the last analysis, a total reorganization of USAETL. If it was not a total burning of bridges, it was at least a burning of organizational charts, with Col. Laubscher literally setting the torch to the old one on 1 October 1986, at a festive party in the Cude Building. On paper at least, USAETL was ready for Col. Laubscher's "Digital Topographic Revolution."



Commander and Director Col. Edward K. Wintz, 1 August 1981 to 30 April 1985



Commander and Director Col. Alan L. Laubscher, 3 June 1985 to 25 May 1988

In search of economy through standardization

There is another side, however, to the laboratories' adoption of digital technologies. The years 1984-1988 provide numerous examples of researchers pursuing the goal of simplicity and economy.

Both the Modular Azimuth Position System (MAPS) and the Environmental Design Guidance for Evaluation (EDGE) work, for example, were efforts by USAETL to use technological advances to create cheaper, more generic systems for field use. Even CAD, an element dealing exclusively with digital matters, had its prime focus on finding ways to standardize certain requirements for DTD. The aim, then, was as much economy as improvement. USAETL's seminal Digital Topographic Data Requirements Study (1984) underlined the need for standardization.

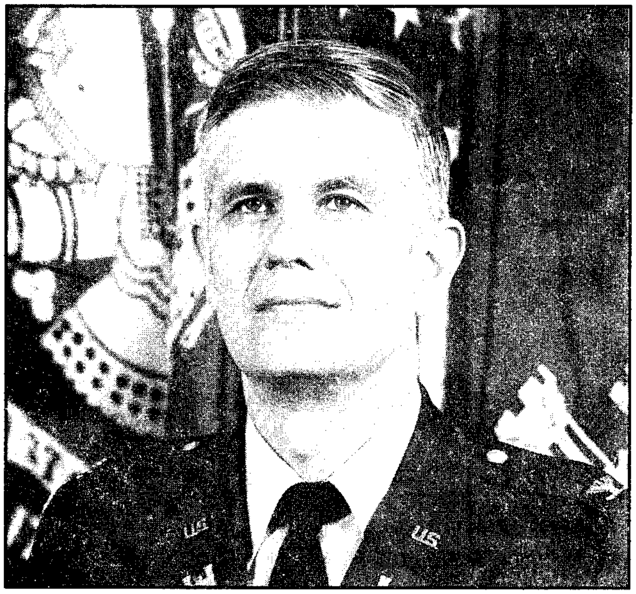
Frank Capece and his CAD team also worked to find a more efficient and economical data base for map background than DMA's preferred map background. The goal was to look into "better ideas" and find "something everyone could use." [Interview with Frank Capece, Fort Belvoir, Va., 26 November 1991.[12]] Many avenues were explored in these years, but it is surprising to the layman to see that an overriding goal was, again, economy.

Exploiting new technologies

One area where economy and improvement went hand in hand was in USAETL's use of the evolving GPS technology. Fulfilling a prophecy by USAETL's Kenneth Robertson, the years 1984-1988 saw this

satellite surveying technique encompass static, kinematic and dynamic survey. Similarly, in the Corps' civil works program, GPS was ever more widely exploited. Originally a small program, the USAETL civil works contingent grew considerably in size and importance in these years, as they perfected techniques to use GPS to monitor dam safety and, with the addition of potentially automated image analysis techniques, to monitor wetlands as well.

USAETL Director Walter E. Boge, 1 December 1991 to present



Commander and Director Col. David F. Maune, 9 June 1988 to 30 November 1991

Footnotes

1. *Army Research and Development Organization of the Year Report for FY88*, p. 2.

2. Interview, author with Col. David F. Maune, Fort Belvoir, Va., 4 November 1991.

3. Interview, author with Col. David F. Maune, Fort Belvoir, Va., 4 November 1991.

4. Interview, author with Col. David F. Maune, Fort Belvoir, Va., 4 November 1991.

5. Interview, author with Laslo Greczy, Fort Belvoir, Va., 16 January 1992.

6. USAETL in-house QRMP brochure, unpaginated.

7. *Army Research and Development Organization of the Year Report for FY88*, p. 1.

8. Briefing by Richard Herrmann, Fort Belvoir, Va., 11 January 1990.

9. Letter in *Lab Lines*, September/October 1986.

10. An Open Letter to former commander and director, Col. Edward K. Wintz (Ret.), *Lab Lines*, September/October 1986, p. 2.

11. Ibid.

12. Interview, author with Frank Capece, Fort Belvoir, Va., 26 November 1991.

Fiscal Years 1984-1988: Key external actions

The Army made a decision to study its deficiencies from a different perspective. Each U.S. Army Training and Doctrine Command school was instructed to conduct a mission area analysis, identifying shortfalls in the ability of the branch to perform its warfighting mission. These shortfalls were divided into groupings such as leadership, organization, doctrine, training and materiel. Materiel deficiencies were grouped into a listing called the Battlefield Deficiency Plan with a 1 to n ranking in priority order.

Meetings were held to determine what technology was being developed within the Army research and development program to solve or mitigate the identified deficiencies. The meetings were conducted based on Department of the Army Mission Areas: Close Combat, Combat Support, Command - Control - Communications and Computers (C^4), Fire Support, Air Defense, Combat Service Support, and Training. It fell to the Plans and Programs Office of the USAETL staff to sort out those technologies which would apply to the more than 300 deficiencies which had been identified, and to present them in such a way as to obtain support from the mission area chairman.

Most of USAETL's technology was applicable to two of the mission areas - C^4 and Combat Support. Following a month long series of meetings, the USAETL program for the Digital Topographic Support System (DTSS) was reinforced with funding increases from both of those areas and given strong verbal support by Fire Support as well. This process continued throughout the years covered by this history with support generally strong when faced by specifically defined deficiencies. The ubiquitous nature of topography on the battlefield and its importance as a force multiplier always resulted in strong support, making the development of both the DTSS and Quick Response Multicolor Printer a reality.

During this period the Army placed renewed emphasis on the use of space assets to support combat operations and planning activities. The Department of the Army instructed the U.S. Army Materiel Command to review the Army's role in space and propose new programs to take advantage of the newly established Strategic Defense Initiative. When it responded with several programs, ranging from Army Space Program Office developments to DTSS and Computer-Assisted Photo Interpretation Research, USAETL was immediately added to the list of study participants. Following a briefing to the Deputy Chief of Staff Operations, an Army Space Technology Working Group (ASTWG) was established, with membership coming from those developmental activities which had space-related programs. The USAETL Programs and Resources Office staff played a leading role in this committee, eventually pulling a team of USAETL engineers together to write the final ASTWG report. This report correlated information from a number of sources to give a clear picture as to where the Army was in space and how it could best invest its funds to secure immediate, as well as long-term benefits.

One of the major components of the final report of the ASTWG was a report on Army Space prepared by a task force located at Fort Leavenworth, Kan. This 30 man organization was given 6 months to study space activities and develop a series of recommendations as to where the Army could best spend its limited funds to get the most from its investment. Several USAETL research and development programs were included in the recommendations of the Task Force with DTSS being named the first priority for the receipt of funds to support space use on the battlefield.

One outgrowth of the space study activity was the formation of the Army Space Technology Research Office (ASTRO). USAETL played a strong role in the establishment of ASTRO and provided its first deputy director, Dr. Richard Gomez, and a number of its initial technical staff.

Topographic Developments Laboratory

Surveyor in the field

Realizing the promise of DTD

During the years 1984-1988, researchers in the Topographic Developments Laboratory (TDL) at USAETL continued in their quest to find new and better ways to make use of topographic information. Among the goals in the laboratory were developing ways to better exploit Digital Topographic Data (DTD), and improving survey techniques and terminal guidance systems based on topographic data in unique formats.

It is important to note some major changes from the outset, such as USAETL's new role in managing the demand for DTD, the decline in emphasis on the *process* of automated cartography as such and the growing emphasis on making maximum use of the *product* of the mapping process.

Throughout the years, and throughout all the work on streamlining the mapmaking process, a major USAETL goal had always been to provide the commander with the most intelligible, up-to-date terrain information product. TDL could point to real gains here, and in some aspects of the mapmaking process as well.

Similarly, in survey and point positioning research, progress was considerable. But with the Global Positioning System (GPS), advances were made along both fronts — with the product *and* the process. In other areas at TDL, gains were real but not so universal or predictable.

On a tangible level, TDL followed up USAETL's 1984 landmark Digital Topographic Data Requirements Study with the formation of a special Concepts and Analysis Division (CAD) to monitor the explosion of demand for DTD. This was in response to a large number of emerging systems exploiting technological advances using DTD and the personal direction of the vice chief of staff of the Army. This also was at a time when its availability as a family of standard products remained a question.

Yet, the appetite for such advances was hardly going to diminish, for the Army's increased capability for rapid movement under all weather conditions and the need for highly coordinated fire support meant that the need for terrain familiarity was greater than ever. Similarly, ever more advanced missile guidance systems were emerging, using terminal guidance relying on terrain information in some form. Accordingly, TDL pursued initiatives on many fronts, much of it intended to improve positioning, navigation and system development to supply terrain information.

The "Digital Topographic Revolution" at TDL focused heavily on exploiting topographic data in the years 1984-1988. This meant not only making full use of emerging technologies, but also adapting, or even creating, some of those technologies within the laboratory itself.

1. MANAGING THE DEMAND FOR DTD

By the beginning of the 1984-1988 period, engineers and scientists both within and outside the Army were planning systems to take full use of the possibilities inherent in DTD. Unfortunately, the user community had an imperfect understanding of what DTD support could be expected from the Defense Mapping Agency (DMA).

Though researchers were understandably eager to show the marvels that could be wrought by systems run on DTD, the same researchers were less zealous in examining the harsher realities of supply and demand. Too many systems designers simply assumed that DTD support was going to be there when their system was fielded. They were, in Frank Capece's words, "oblivious to the data production bottleneck." [Interview with Frank Capece, Fort Belvoir, Va., 26 November 1991.[1]]

The wonders that could be worked by systems designed to use DTD had blinded developers to the fact that DTD might not be available to support them. Some of this could be attributed to the fact that so much past emphasis had been placed, and so much of DMA's time and fiscal budget expended, on providing DTD for now-uncritical areas such as the Fulda Gap in Germany. But the heart of the problem was the bottleneck in DTD production, which was in many ways a modern reflection of the long-standing mapmaking bottleneck. Neither was likely to vanish anytime soon. Thus, when systems approached completion, developers were often forced to scramble to create data bases to support their systems — with unfortunate results. USAETL's Commander and Director Col. David F. Maune put the situation this way:

"This results in the proliferation of nonstandard, incompatible data bases and software which is costly for the government in terms of both recurring development costs and maintenance costs. In many programs, this also means that costly data bases are only produced for unique training scenarios and would not be applicable for rehearsals of actual missions on different pieces of real estate." ["TEC to support simulation systems and programs for DTD exploitation," *Digital Data Digest*, Vol. 2, No. 1, Fall 1991, page 2.[2]]

DTD in short supply

At this point, it is essential to remind the nonprofessional of the same thing the systems developers had to learn: that producing DTD was still a slow, tedious and highly skilled process. No matter how sophisticated a system might be, there was still the requirement for the digital "fuel" needed to run it. Yet, due to the slowness of the process whereby imagery is converted into DTD, that fuel was still in short supply for many areas and likely to remain so for some time.

Yet, demand was growing, both in sheer volume and in specificity. This was increasingly at odds with the fact that DTD was not available for many parts of the world at all, and still less so in precisely the exact format a specific system might require. A host of technical reasons for this could be cited for individual cases, but the underlying difficulty often related back to the slow labor of turning aerial imagery, or whatever terrain information, into DTD, in whatever form.

Reaching a critical stage

Some pessimists argued that this shortage of DTD was endemic to the process of converting imagery into maps. But the significant point was that even the optimists recognized that the designers of such emerging systems needed to be made aware of what DTD support they could expect both near- and long-term. Only in this way could they tailor their demands to reality. At any rate, it was apparent to all concerned that the DTD situation was reaching a critical stage.

USAETL always had been at the forefront in exploring the uses of DTD. Thus, one might expect that,

when the demand for it threatened to get out of control, the laboratories assumed an almost regulatory role, based on in-house expertise. Indeed, CAD, later to become the Digital Concepts and Analysis Center (DCAC) in 1989, was created to manage DTD. Its creation can be seen as a major part of the "Digital Topographic Revolution."

Emergence of CAD

There was a need for an entity, not only to referee the scramble for existing DTD support, but also to oversee the demands for future DTD products. The creation of CAD must be seen in the context of assuring that systems project managers got what they needed. And, above all, that systems not be developed that could not be supported by DMA standard products.

USAETL standardizing requirements

A great deal of research also went into reducing the complexity of equipment in the interest of broader and cheaper applications. Other scientists at the laboratories (e.g., those perfecting devices designed to determine point positions such as the Modular Azimuth Position System) have worked to simplify technologies to the lowest workable common denominators. Obviously, if the Army can use a piece of equipment in many places, there are big savings in production costs; and the same is true of high-tech components and DTD.

But the trick has been not to negate that gain by having the generic product be over designed for many projects — much like a cold remedy that treats nine symptoms when the patient only has one. Then, on the other hand, there is the possibility of under design, where the product has to be modified subsequently to work at all in many specific cases. The right product, obviously, must walk a very fine line.

CAD's mission

This fine line only gets finer when one looks to CAD's mission. Its task was not merely standardizing a device, but standardizing entire data sets. It was CAD scientists who had to decide who within the whole Army's digital terrain data user community was to get what data. Implied in this is CAD's role in influencing what kind of data should be produced by DMA — at a time when, as researcher Richard Herrmann put it, there was "an explosion of need" and a lot of people standing in line. [Briefing by Richard Herrmann, Fort Belvoir, Va., 26 January 1991.[3]] Setting priorities, as well as defining standards, was at the heart of CAD, and later, DCAC's mission.

The creation of CAD and the evolution of this very important mission must be counted among the most important events at USAETL in the 1984-1988 time frame. For, as USAETL's Douglas Caldwell observed:

"We now could do so many things — almost too many things — with Digital Topographic Data. It was time to find out who really needed what and in what form. We needed to concentrate on the user." [Interview with Douglas Caldwell, Fort Belvoir, Va., 22 May 1991.[4]]

It was to be DCAC's mission to see who really needed what, and when. Only then could the center succeed in "trying to avoid specialized data bases" by "defining a standard one." [Interview with Frank Capece, Fort Belvoir, Va., 26 November 1991.[5]]

Thinking DTD

When USAETL used its Field Exploitation of Elevation Data (FEED) demonstrator and USAETL studies to get the Army to start "thinking digital topographic data," it succeeded perhaps all too well. [Capt. David Gallay, *Tech-Tran*, Vol. 6, No. 3, Summer 1981, page 2.[6]] While DTD might prove to be the panacea some scientists promised, it remained to be seen whether such data could be produced by DMA, either to the required specificity, or in the required quantity. To even hope to answer that question, USAETL needed to know who would be the user and for what purpose.

To that end, the Terrain Information Systems Group, initially under Regis Orsinger and then under Frank Capece, began an evaluation of two DMA prototype data bases in 1981. This, in turn, "snowballed" into the complete Digital Topographic Data Requirements Study in 1984. It was to be a milestone: the first time total Army requirements for DTD were stated and approved by the Department of the Army.

Legacy of 1984 DTD requirements study

The DTD study was carried out from 1983-1984, and supplemented in 1987. It turned out to be, in the words of TDL's Orsinger, "one of the most important activities undertaken by USAETL in these years." He saw the study as "awakening topographic programs from the doldrums of the 1970s." [Interview with Regis Orsinger, Fort Belvoir, Va., 1 July 1991.[7]] It accomplished this by demonstrating a pressing need to get control of things with regard to DTD.

The appetite for DTD already was getting out of control in three areas: Army terrain analysis; Army analysis community needs (such as modeling, simulation, and training); and the tactical systems and programs such as smart missile guidance.

The worry was that systems with very specific

requirements were being designed and built without regard to whether DTD was then, or even in the future, likely to be made available to support such systems. And, in fact, one USAETL researcher flatly noted that it was still "impossible to meet individual systems' needs." [Briefing by Richard Herrmann, Fort Belvoir, Va., 11 January 1991.[8]] There also was concern about wasteful duplication of effort in different systems, and finally, the sheer weight of the work load being laid on DMA.

Identifying users and their needs

The DTD study sought to identify all known and anticipated Army systems needing some kind of DTD. It also provided a unified statement of Army needs, which was formulated as a specification for a digital topographic data base to support Army users. The latter, called Tactical Terrain Data (TTD), was the first real push to, in Col. Maune's words, "focus on product standardization." [*Digital Data Digest*, Vol. 1, No. 3, Winter 1991, page 1.[9]]

And it proved to be quite a focusing effort. The result was a 4-volume, 700-page document identifying 75 Army systems that either already required or anticipated a requirement for DTD. The count included 31 tactical systems; 26 systems or programs for simulation; training, test and development; and 18 systems for the analysis community.

Clearly, USAETL had convinced the Army of the merits of DTD, but now the availability of data and its quality looked to be a real "problem area." [Interview with Frank Capece, Fort Belvoir, Va., 14 October 1984.[10]] By 1985, the majority of tactical or analytical applications, even assuming data were available, had a requirement to the 1:50,000-scale specification for a standard DTD product. No existing DMA products met these standards, to say nothing of the more stringent needs of simulation, training, test and development users (who wanted a 1:12,500-scale specification).

A continuing problem

USAETL's 1984 DTD study had revealed a mushrooming need for what could, in all probability, not be provided. Yet, the Pershing II missile, to cite just one system, had been so successful and had turned so many heads that no one expected the demand for DTD to subside.

On the contrary, despite the likelihood of shortfalls in DTD support, systems continued to emerge that needed DTD support. The critical need to get some kind of management underway was effectively underlined by the original DTD study, but a further look was clearly needed. In 1987, a follow-on survey (see below) would show that the problem had only grown more critical, with the number of users more than tripled. The problem had changed from demonstrating the virtues of digital data (1979-1983) to controlling the appetite for it (1984-1988). Squarely in the middle of the two periods, the DTD study provided DMA with a picture of what Army systems were likely to need.

Lessons of Grenada

The pressing need to get a handle on the DTD problem became even clearer when viewed against the background of "Operation Urgent Fury," the October 1983 military operation on the island of Grenada. Maj. Gen. Robert F. Durkin, director of DMA, looked back at Grenada as a wake-up call to the inadequacies of crisis support:

"... military elements could not communicate because of incompatible radio frequencies . . . paper maps of limited utility were not available for the first 72 hours." ["Charting a World of All-Digital Maps," *Defense*, 1988, page 20.[11]]

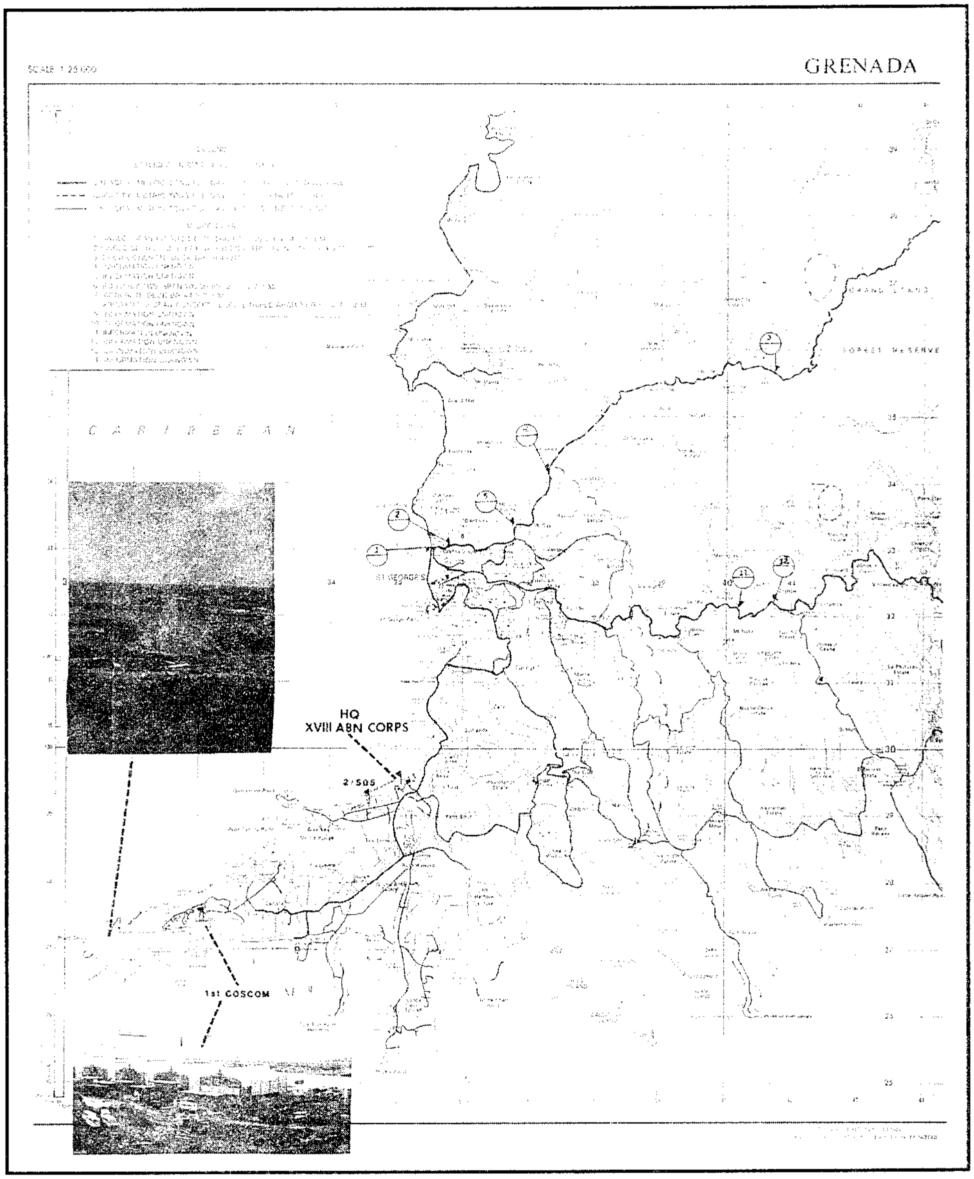
DMA had not, in fact, been called upon until the Grenada operation was virtually underway, [Ibid., page 21.[12]] but even if it had been, Maj. Gen. Durkin envisioned the potential problems:

"Consider a situation where the ground forces are working from digital map information displayed on an "Army" set of hardware and/or software. Air Force supporting aircraft are using different frames of reference, while offshore Navy-directed artillery support comes from yet a different set of specifications." [Ibid.[13]]

Writing at the end of the 1984-1988 period, Maj. Gen. Durkin still considered this scenario "only too possible." [Ibid.[14]] Addressing the same problem from the other end, Col. Maune would stress the need to "focus on product standardization" to avoid waste and ineffectiveness due to data or software incompatibility. [*Digital Data Digest*, Vol. 1, No. 3, Winter 1991, pp. 1-2.[15]] "No doubt," said USAETL's George Simcox, looking back in 1990, "a big push came from Grenada." [Interview with George Simcox, Fort Belvoir, Va., 11 January 1990.[16]]

What kind of DTD?

USAETL's Herrmann saw an "impossible situation," [Briefing by Richard Herrmann, Fort Belvoir, Va., 11 January 1991.[17]], with the very real possibility that expensive, fully developed systems might come on-line unsupported — without the DTD they required to



Map of Grenada

function. Maj. Gen. Durkin concurred:

"... the exploding development of highly sophisticated off-the-shelf hardware, in dozens of forms, already is at the disposal of, or perhaps even already acquired by, military systems operators — often with unfounded assurances from the vendor that this gear is capable of using digital data generated by the Defense Mapping Agency." ["Charting a World of All-Digital Maps," *Defense*, 1988, page 22.[18]]

In 1985, only five systems of the 75 users identified in the DTD study could be validated for support from DMA, and only three of those five were even getting it. Even more ominously, all three of those actual users were getting data to a specific systems specification and format. There was no possibility at all that such specialized support could have, or even should have, been supplied to the other 72 candidates.

What kind of DTD and to whom?

The laboratories' cartographers, familiar with the painstaking work involved in turning aerial imagery into maps, testified that creating even ideally standardized DTD was slow, hard work. Indeed, the mixed record of USAETL's many efforts to automate aspects of cartography in this period provides strong evidence that producing DTD was going to be hard going for some time to come.

As a consequence, DMA anticipated facing some daunting assignments. Maj. Gen. Durkin cited a work load fully proportional to the aforementioned "explosion of need":

"These growing requirements are staggering. The Air Force has requested digital high-resolution products that would require more than 1,000 man-years of DMA

effort. The Navy's growth projections are similar to the Air Force, while the Army projects requirements for extensive coverage at 1:50,000-scale that could result in more than 30,000 man-years of the agency's effort."

Both Col. Alan L. Laubscher and his successor, Col. Maune, recognized that USAETL, insofar as it had researchers working on both defining the problem (e.g., the DTD study) and solving it (e.g., projects related to long-term automated cartography), was in a unique position to help. The only question was how.

Gen. Thurman's 1985 visit

On 9 December 1985, USAETL's DTD specialists held a briefing on laboratory space activities for the vice chief of staff for the Army, Gen. Maxwell R. Thurman. At the meeting, Gen. Thurman expressed the fear that the Army's appetite for DTD was out of control, and that there was an urgent need to control and coordinate DTD requirements to make sure they were not being overstated.

From this meeting arose the burning question: who was responsible for digital terrain information? The answer, in the course of the meeting, proved to be "no one." Simcox called this predicament "an order of magnitude disconnect," a suitably scientific expression for "a mess." [Interview with George Simcox, Fort Belvoir, Va., 3 March 1990.[19]]

In a "Star Wars marathon," USAETL hosted a long, 9-hour meeting with DMA, the users and concerned parties within the Army, to try to hammer out a plan for managing the DTD requirements explosion. In the course of that meeting it again became clear that "no one knew who was responsible" for dealing with the problem.

Gradually it was decided that a specific entity would have to be created to accept this challenge. On the basis of both tradition and expertise, the finger came to point at establishing a new entity at USAETL.

An organization to regulate DTD

The upshot of the meeting was the revision of several Army regulations to include a U.S. Army Corps of Engineers responsibility for reviewing all DTD requirements. That responsibility was turned over to a new technical operating element at USAETL. This came to be called the Concepts and Analysis Division (CAD).

This new element was to ensure that: Army systems got the standard DTD required to perform their mission; Army systems were able to use the DTD directly, without transformation, on the media provided; and Army systems apply standard solutions to common problems. To do all this, however, would necessitate not only understanding the DTD requirements of the present (as the 1984 study had done), but also anticipating the requirements of future systems.

Key memorandum in 1985

Frank Capece cited a key Program Decision Memorandum in 1985, allowing the Army to get more control over systems development. This memorandum stated that DMA would now require the developer to assume the cost of any special data set. Capece called this "a pivotal memo forcing us into a philosophy of Army-wide data sets rather than system-specific." [Interview with Frank Capece, Fort Belvoir, Va., 26 November 1991.[20]]

To this point, given the traditional primacy of strategic over tactical concerns, DMA had no land-combat data set at all. Now, USAETL would lead the push for what would come to be known as Tactical Terrain Data (TTD). This standard data base, which should be seen as the direct result of the USAETL standardization initiative finding its origin way back in the Requirements Study of 1984, was acknowledged as a requirement by DMA in 1988. [Interview with Frank Capece, Fort Belvoir, Va., 26 November 1991.[21]]

Army digital data requirements forecast: 1987

In 1987, USAETL specialists David Scott, Capt. William Foshay, Robin Lambert, Jeffrey Messmore, Randall Nagel and Regis Orsinger supplemented the 1984 Capece DTD study with an update on likely DTD requirements for the years 1987-1993. The end year 1993 was chosen because that was the earliest forecast date for the availability of the still-developing, state-of-the-art TTD from DMA.

The general intent of the 1987 study was to clarify the situation further regarding near-term tactical DTD requirements. The fourfold purpose was stated as follows:

1) to "identify and baseline" those requirements,
2) to "assess and analyze" them,
3) to "identify emerging DTD-related issues" and
4) to "recommend actions to facilitate near-term DTD support." [*Army Tactical Digital Terrain Data Requirements Forecast* (ETL-SR-1), Fort Belvoir, Va., July 1987, page vi.[22]]

To that end, 150 Army systems were inventoried by USAETL researchers, and 14 were identified as having, or potentially having, near-term DTD requirements. [Ibid.[23]]

Five key findings

Studying the many emerging systems that hoped to be supported by DTD led CAD's researchers to state five "major findings" along with some attendant concerns and recommendations. In general, the USAETL team found that Gen. Thurman's concerns, first expressed two years before, had been well justified.

First, the researchers determined that half the requirements for available DTD products — Digital Feature Analysis Data /Digital Terrain Elevation Data (DFAD/DTED) were undocumented, but if they did become so, the demand for DTD products could increase by two-thirds in the near term. Second, they noted that requirements for future DTD products, TTD and Special Terrain Data (STD) were undocumented, and demand for them could increase eightfold in the near-term. Third, they found a strong likely demand for Electronic Map Data (EMD), emerging as a "critical requirement" from the study. Fourth, the study group observed that not all developers had "actively addressed" the issue of transforming DTD into what they needed. Fifth, they noted the existence of DTD requirements within the Army that fell outside the scope of their study. [Ibid., iv-x. [24]]

Addressing concerns for the near-term

Each of the above findings, in turn, created concerns for the near-term that were spelled out by the DTD team, along with some helpful recommendations.

The problems with available DTD products revealed that **a**) the volume of undocumented requirements for DFAD/DTED might swamp transformation facilities; **b**) the data itself was "inadequate, inappropriate, or unavailable for many applications;" and **c**) a "basic lack of understanding" prevailed about the product's content, resolution and accuracy.

USAETL recommended the Army, through CAD, assist the various project managers by both providing analytical support and furnishing an information service on available DTD from DMA.

With regard to future DTD products, TTD and STD, the team expressed concerns about TTD's role in the near-term. It was found that **a**) TTD was "not a realistic information source" for the systems to be fielded prior to 1993 because the systems fielding dates did not correspond with TTD production schedules; **b**) TTD was still being defined, and that it was crucial to make it compatible in the future with what was being fielded then; **c**) that the Army might have to find a way to secure its own TTD if DMA could not produce it in time — or be faced with degraded systems capability; and, finally, **d**) that production of the even more accurate and detailed STD would not be extensive due to the cost and labor involved.

CAD's study team recommended that CAD itself establish contact with those developing the 14 identified systems in order to make sure that "their combat effectiveness is not compromised by the lack of quality DTD," and urged prospective Army users of TTD/STD to make an effort to use then-current DMA products for the near-term. [Ibid., viii. [25]] The researchers also wanted studies made into the incremental system performance benefits of TTD/STD over the current product.

The aim, as always, was to make sure that emerging systems could be supported, and to determine what was the best and lowest common denominator for that support. To that end, the report urged the Army to obtain a TTD prototype by the end of 1987, and discouraged demands for extensive coverage using STD.

The emergence of EMD as a "critical requirement," in turn, led the study team to express a number of concerns. The researchers noted that half the requirements were undocumented and, even those that were documented, varied widely. The resulting situation had prospective EMD users seeking solutions directly from contractors. Similarly, alternate technologies were being sought by project managers, including video or optical discs.

The report recommended that the Army assist project managers in formulating their request for EMD. Not surprisingly, the researchers pushed for standardizing those requirements, and recommended making use of CAD's help in all this. CAD researchers further urged that the Army develop a recommended position on electronic map displays, against the background of a review of EMD requirements of other services and the production capabilities of DMA, which offered ARC-Digitized Raster Graphics (ADRG) instead.

The DTD forecast saw many problems associated with transforming 9-track, DMA-supplied DTD to an individual systems' storage medium. The researchers noted that DMA was likely to standardize on a limited number of media/formats that might end up not supporting Army users fully.

The study concluded that the Army needed to work with project managers to assist them in reducing media/format requirements to a minimum. CAD was among the suggested agents for this work. It was further recommended that the Army develop a centralized capacity to transform DTD for the Army user. DMA, in turn, was to be requested to support future media/format output standards for digital products.

In addition, the study team noted "many other DTD requirements" within the Army that did not fall within the purview of their report. They expressed the concern that these too would be part of a trend that would cause requirements to "mushroom," increasing the need for analysis and control. [Ibid., page ix. [26]] This was particularly ominous when such analysis and control was not likely. The report flatly stated: "Regulatory

controls to ensure early review of Operational and Organizational Plans, Required Operational Capabilities, etc., are weak." [Ibid.[27]]

The study observed that Army resources to manage DTD also were limited and urged they be increased. The researchers also underlined the need for the Army to strengthen the appropriate regulations to provide for "constructive review of all emerging requirements." Again, CAD offered to continue active review and analysis of DTD requirements and pushed for study of the possible requirements of systems outside the scope of the 1987 study.

Importance of 1987 study

The 1987 DTD study went beyond the 1984 DTD Requirements Study. Not only did it identify more potential DTD users, but it strove to get some kind of managing control over future requirements in the near-term.

If the 1984 study could be said to have defined what DTD support the Army should request and what DTD DMA should produce, then the 1987 study can be said to have disciplined the Army systems project managers with regard to what they could expect in the way of DTD support. By 1987, CAD could expect some Interim Terrain Data support from DMA and had a commitment for TTD in 1993. TDL director Orsinger saw the studies having an effect "well into the 1990s." [Interview with Regis Orsinger, Fort Belvoir, Va., 1 July 1991.[28]]

Setting the standard: map background economies

CAD not only pushed for standardized data bases, but sought to assure that the agreed-upon standard was as economical as possible. A good example of this effort took place in the domain of map background where Orsinger's team sought to reverse what they thought to be an "extravagant" DMA standard ADRG map background that had emerged out of a 1986 AV8B Harrier jet requirement. [Interview with Frank Capece, Fort Belvoir, Va., 26 November 1991.[29]] The selection of ADRG as DMA's official map background had been announced with no discussion at a June 1987 symposium at DMA.

CAD researchers suspected, however, that being of such very high resolution, ADRG would require a large amount of storage, especially with its 24-bit color combinations. They quickly determined that an ADRG 1:50,000-scale map would take 76 megabytes, and that "most tactical systems lacked that kind of storage, and many maps are needed." [Ibid.[30]]

CAD's researchers, who had expected more discussion on alternatives, set about looking for "something cheaper and better that all systems could still use for visual reference." [Ibid.[31]] As the 1984-1988 period closed, CAD was looking at map background with as low as 4-bit color as a "better idea." Using his requirements study experience, Orsinger also spearheaded a quick study identifying 13 systems needing backgrounds different than ADRG.

Role of CAD

Apart from the widely circulated DTD reports, CAD's service-wide evaluation of requirements served to "provide a real focus to efforts in CAD and, later, DCAC." [Interview with Regis Orsinger, Fort Belvoir, Va., 1 July 1991.[32]] Those efforts, in effect, entailed managing the support side of the Digital Topographic Data Revolution. USAETL had played an historic role in getting the Army to "think digital topographic data." Now, in giving USAETL its new role at DCAC, the Army was asking USAETL to help control the appetite it had done so much to create.

At the start of the 1984-1988 period, DMA's DTD support was largely in the form of DTED, and then largely to the Air Force. By the close of the period, DMA was committed to a standard product (TTD) capable of supporting a large number of Army customers. The role of CAD, following upon the two DTD requirements studies, was to assure that optimum use was made of this support. The evolution of this responsibility is a major story at USAETL in the 1984-1988 years.

2. SURVEY AND POINT POSITIONING

Certainly, one of the truly long-term problem-solving efforts of TDL, past and present, has been to find ways to improve the speed and accuracy of survey. But it is perhaps a measure of the laboratory's success that "point positioning" began to replace the very term "survey" in the lexicon of topographers during this historical period. The methods and technologies employed during these years had changed that much.

One highly promising initiative, finding Army survey applications for the Global Positioning System (GPS), was considered so revolutionary in so many areas that it was hailed as the "next utility." This was a reflection of the many possibilities of GPS technology for both military and civilian applications. USAETL scientists were among the first to recognize this, and, as always, research was carried out with such technology transfer "spin-offs" fully in mind. The unique opportunities for cross-fertilization possible at a laboratory of this kind played a large part as well.

Similarly inventive approaches used inertial technology to create systems which would determine horizontal and vertical coordinates and azimuths with geodetic accuracies, determine gravity anomalies, and

calculate gravity deflections of the vertical. Researchers also worked toward systems that provide three-axis measurements of vehicle attitude and attitude rates, as well as position.

New approaches in survey and point positioning

But pursuing a new approach is never easy, as even this brief account of the many efforts on many fronts shows. There were some dead ends, some successes, and other successes that were "overtaken" by even greater successes born of parallel research within the same building. The end result, however, was ever-better point positioning survey technology, enabling the commander to know where he was, both more quickly and with greater accuracy.

It should be noted that here, in the highly technical world of survey technology, the process was being significantly speeded up, along with significant improvements in the accuracy of the product. Fellow USAETL researchers in mapping and terrain products would have been pleased to say as much; but, of course, the problems being addressed were very different.

GPS: perspectives on magic in the air

The late R. Buckminster Fuller, inventor of the geodesic dome, argued that most of the great leaps forward in human science take place in the "outlaw regions" of human experience, where the inventor is removed from both conventional method and conventional settings. The two great prominent laboratories of such invention, according to Fuller, were military innovation and resourcefulness at sea. Both these elements, it should be noted, were present in the swift development of GPS.

Need to improve on celestial navigation

The remote cause for developing GPS is to be found in man's ancient need to know where he was and where he was going. At sea in particular, there were few landmarks or perhaps they were lacking altogether. In time, celestial navigation evolved to where one could employ the very best instruments to make out one's location, give or take a mile. This, however, presumed visible stars, and even then, was not much help in finding a small harbor landfall at night. Moreover, celestial navigation required skill and training, and not everyone took to it. Research continued, because sailors needed something easier and better.

The military, in the meantime, both on land, at sea and in the air, needed something better as well, in order to know where they were and to know where things were (so they could shoot at them if they need to). Accordingly, the reason for the development of GPS was the Department of Defense recognizing the need to significantly improve upon the Navy's TRANSIT Satellite System. As TRANSIT came into use, satellite position fixes were typically taken from a moving vessel in which each position fix was used independently to update the dead-reckoned position for navigation purposes.

Survey from satellites

But as Fuller would have anticipated, the late 1960s saw military scientists busily developing equipment to use TRANSIT for surveying. The position of a fixed point was sought from multiple satellite passes at a single location. In such a case, appropriate data processing techniques made it possible to get a useful survey result without conventional land traverse.

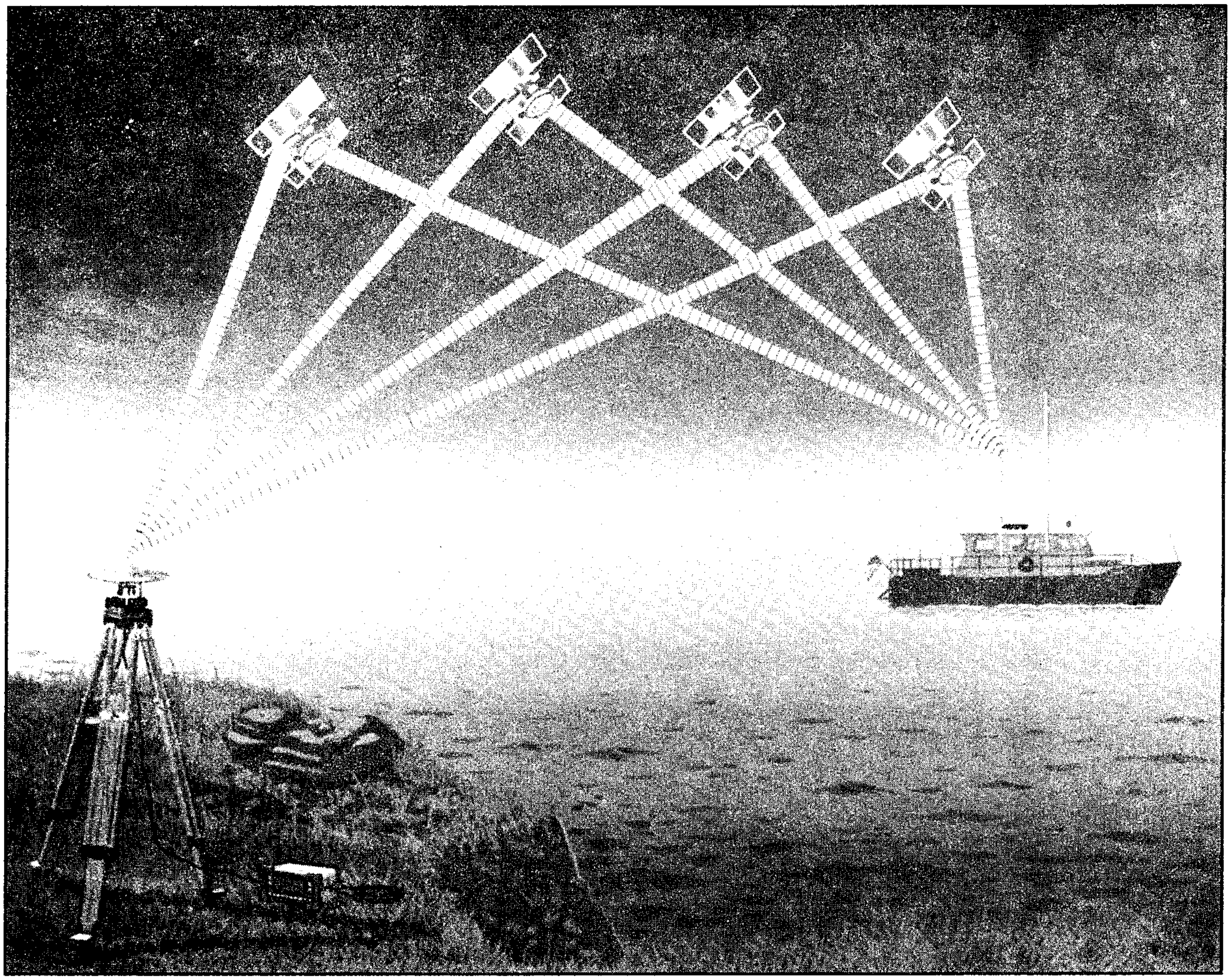
Although taking 25 satellite passes to get a horizontal repeatability of less than 5 meters was still fairly quick for some survey purposes (seismic line control, gravity surveys, control for offshore positioning, mapping control, and utility line control), the accuracy was not up to the standards of other kinds of survey.

The potential was there but there was a clear need for an updated system. The result was NAVSTAR GPS, building on Air Force and Navy systems of the late 1960s, to create a truly revolutionary tool for military sea, land and air navigation. More than that, however, some joined USAETL's Kenneth Robertson in anticipating numerous applications to civil works and surveying.

By testing their interferometry or differential receivers, USAETL scientists showed that, through GPS, costly triangulation networks and running long traverses could become things of the past. Commercially available receivers, growing ever better, smaller, and cheaper, were used to make position determinations of high accuracy in 30 minutes to 2 hours by the middle of the 1984-1988 period.

More and more applications

Those looking for examples of tangible civilian "spin-off" uses of military research need look no further than USAETL's work with GPS. The project was just underway in 1984, when Robertson, foreseeing the vast potential of GPS for both civilian and military use, boldly predicted that ultimately all survey would be "satellite centered." [Interview with Kenneth Robertson, Fort Belvoir, Va., 3 October 1984.[33]] Subsequent years proved him correct, as scientists Dr. Clyde Goad and Dr. Benjamin Remondi with the National Geodetic Survey (NGS) and C.C. Councilman at the Massachusetts Institute of Technology began to look at GPS as a potential measuring device.


Offshore surveying using the Global Positioning System.

At USAETL, research would eventually center around 1) extensive research into Corps applications of GPS technology, and 2) technology transfer to Corps Field Operating Activities. But at the laboratories, one eye always was kept on more imaginative applications. In a later interview, Douglas Caldwell of USAETL's Geographic Sciences Laboratory (GSL) cited project after project that might well be "overtaken" by GPS in the years to come. He pointed to growing uses for a system that had still seemed a remote and expensive option just a few years back.

Monitoring dam safety: a gradual turn to GPS in 1985

An excellent example of judicious expansion of GPS uses had already occurred within USAETL itself. During the years 1979-1983, Robertson had refined a system to improve upon Corps dam safety monitoring, specifically the ability to measure movement in large monoliths. And, of course, the Corps' historic role in the nation's rivers and waterways meant there were a large number of such monoliths to be watched over. Robertson was looking for better ways to carry out this traditional responsibility.

Formerly, such monitoring had involved the use of triangulation and expensive interior plumb lines, but at the very time Robertson was trying out a much cheaper method using trilateration and mirrors, he was confident already in 1984 that even his new and better technique would be eventually supplanted by satellite survey. Indeed, Robertson asserted that dam monitoring would be "just a part of it." [Interview with Kenneth Robertson, Fort Belvoir, Va., 3 October 1984.[34]] And in fact, GPS, when tied to advances in image analysis, would come to play a part in the Corps' expanding role in monitoring construction activities in the waters of the United States.

This insight was to point the way for USAETL geodesists to serve a much larger role in the civil works

area, for it was they who could put satellite survey to use in dam monitoring — and much more.

Better techniques needed

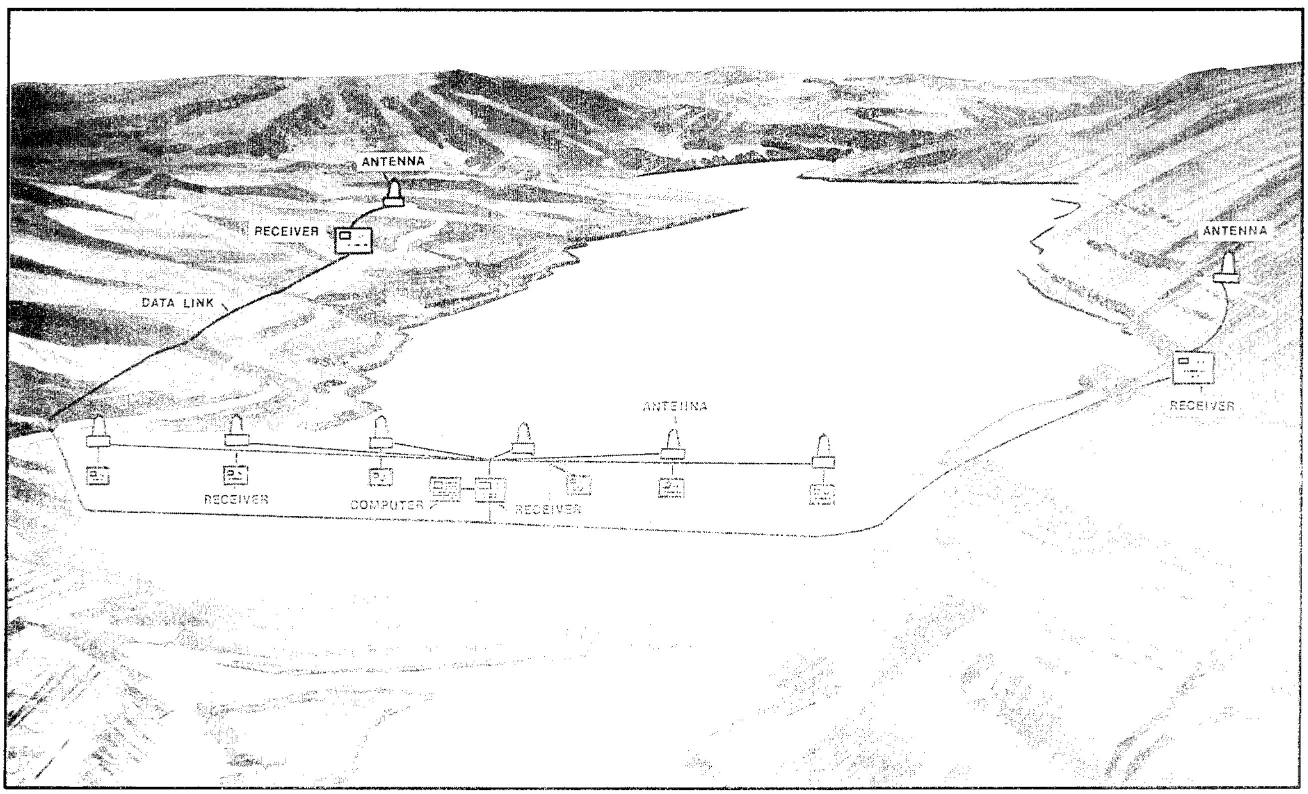
The impetus to apply GPS technology to dam monitoring arose because the classical techniques were too labor-intensive, leading to such surveys being made infrequently. Indeed, 6 to 8 month intervals were the norm, "or sometimes not at all unless there was a suspicion of structural distress." [Stephen R. DeLoach, "Continuous Deformation Monitoring with GPS," paper presented at the 11-14 May 1988, American Society of Civil Engineers' Specialty Conference, "*GPS 88-Engineering Applications of GPS Satellite Surveying Technology*," page 93.[35]] By 1985, when Robertson retired and handed over the growing GPS initiative to Stephen DeLoach, USAETL was on the trail of a better way to monitor its large structures and GPS had become a "hot topic" throughout the scientific community. [Interview with Douglas Caldwell, Fort Belvoir, Va., 7 February 1991.[36]]

Looking for an automatic monitoring system: 1985

With GPS slated to be in orbit all the time, the attractive possibility was to develop a monitoring system that could continuously and automatically monitor monoliths, alert to any deformation.

But the system would have to measure points on the structure relative to stable reference points, while achieving a precision of 5 millimeters over distances as large as 5 kilometers. Such a system also would have to operate continuously, require little attention, be easy to install and maintain, while staying reliable. Then too, in a time of shrinking budgets, USAETL scientists wanted a system that could be run as cheaply or more cheaply than conventional techniques on a cost-per-point-measured basis.

There were other possibilities, such as the Very Long Baseline Interferometry that measured "star noise," but the Fort Belvoir researchers liked the economy and potential portability of a GPS-based system. [Interview with Stephen R. DeLoach, Fort Belvoir, Va., 6 May 1991.[37]] USAETL and NGS scientists concluded that contemporary GPS technology already permitted the possibility of a continuous monitoring system for structural deformation studies. [Stephen R. DeLoach "Continuous Deformation Monitoring with GPS," paper presented at the 11-14 May 1988, American Society of Civil Engineers' Specialty Conference, "*GPS 88-Engineering Applications of GPS Satellite Surveying Technology*," page 99.[38]] But they also noted the need to develop additional software, plus hardware installations carefully designed to link the equipment and minimize "various error sources." [Ibid.[39]]



Overall view of the Continuous Deformation Monitoring System.

Customizing a GPS system at USAETL: 1986-1988

In September 1986, USAETL researchers began upgrading their six GPS receivers and equipment to include 10 tracking channels, more stable micro strip antennas, internal data logging and enhanced post-processing hardware. By 1988, the Survey Division's researchers were employing so-called pseudo-kinematic survey using GPS. This technique, borrowed from the Department of Commerce, allowed the survey crew to establish positions on a station within seconds, whereas previous techniques had required an hour or more. Thus, it became possible to plan on completing structural deformation in a single day instead of budgeting for a whole week. Following TDL's demonstration of these further possibilities, GPS manufacturers quickly saw the merits of the upgrade and customized their software to suit the new technique.

Selling the idea of GPS: 1987-1988

The very nature of geodesy, a self-admitted "dark and forbidding area for the layman" [Capt. R.K. Burkard, *Geodesy for the Layman* (St. Louis: Aeronautical Chart Information Center, 1968), page 1.[40]], meant that USAETL had its customary selling job to do. The technology had to win over the experts and, last but not least, those who would ultimately use it. Dam monitoring, where it already had shown promise, was just part of the picture.

In 1987, a Coast Guard team demonstrated that GPS could calculate the position of a moving platform with a 3-5-meter accuracy. In the spring months of the same year, the USAETL system was taken to Corbin, Va., to a facility of the NGS. Here, the scientists made use of the test quad designed to evaluate a variety of surveying instruments. Through extensive field testing, the system's positional standard error was estimated.

Remeasuring Mount Rainier: 1988

USAETL's most tangible GPS demonstration effort involved helping the Corps' Seattle District remeasure Mount Rainier in July 1988. Indeed, DeLoach helped the climbing team carry the GPS equipment in backpacks to Columbia Crest, a mound of rock located at the mountain's top, some 14,410 feet above mean sea level. It was, as USAETL's *Lab Lines* drolly observed, an expedition taking "survey technology to new heights." [*Lab Lines*, Vol. 9, No. 5 (September/October 1988), page 1.[41]] DeLoach cited the educational value:

"With this expedition we were hoping to introduce the technology to a lot of surveyors who didn't know anything about it. We also wanted to introduce the technology to the public, as well as enhance the image of the professional surveyor. I feel we accomplished this." [Ibid.[42]}

In putting GPS to new, highly visible uses, USAETL engineers continued a tradition of making complex technology understandable and letting the man in the street see where his research dollar was going. Though remeasuring the mountain had provided only minor adjustments to the results of former, conventional surveys (14,411.1 feet above sea level), the results were obtained by means of a method that stood to change the very nature of future surveying.

GPS applications a "hot topic" for the future

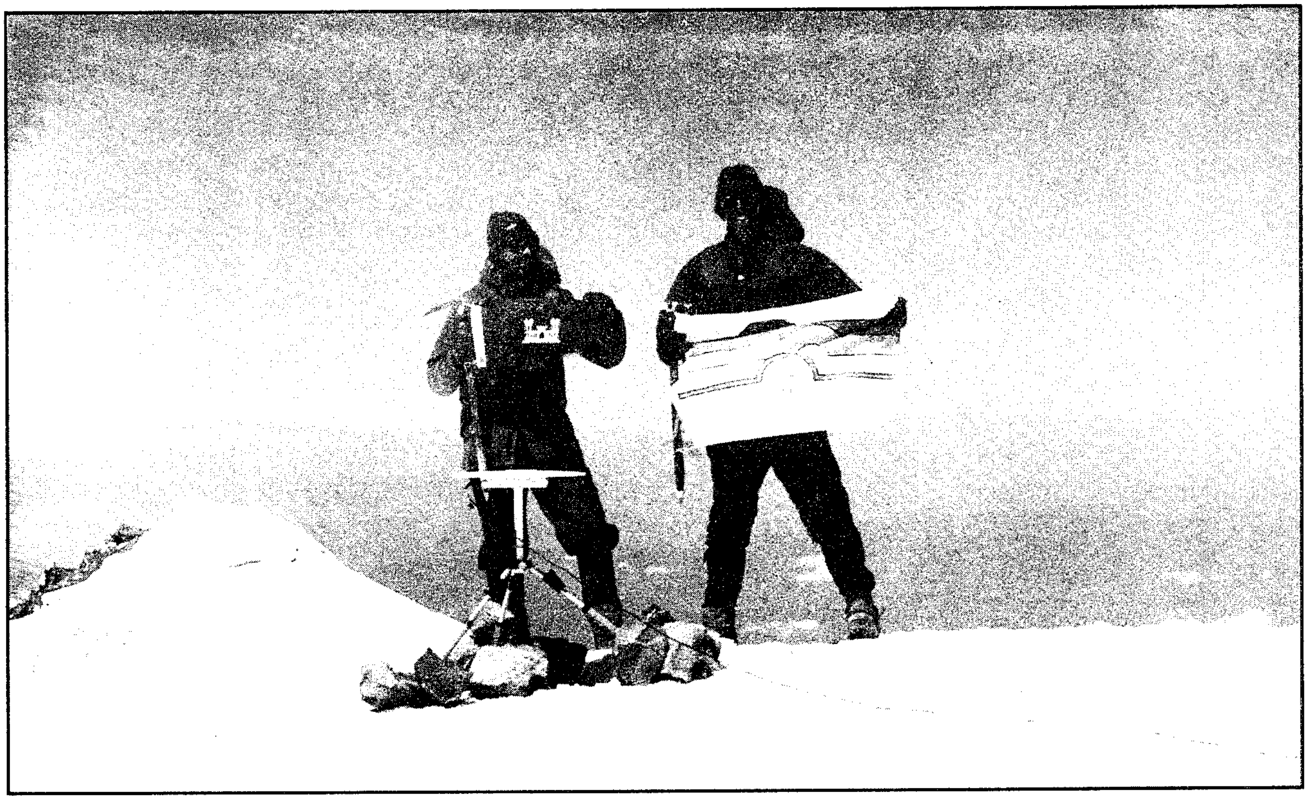
In 1988, USAETL completed the preliminary design for a navigational test course that sought enough high accuracies to let Corps districts calibrate existing systems for hydrographic survey positioning. Meanwhile, the civil works engineers began data analysis toward developing a GPS-based positioning system for the dredges and hydrographic surveyors (GPS with an accuracy of 1-decimeter in three dimensions). This new system promised to be a potential big money saver in regulating and evaluating civil works projects. Throughout this work, the researchers continually reviewed the technology as it was evolving, and kept an eye open for still more applications to the Corps' mission.

Plans were underway to install a GPS monitoring system on the Dworshak Dam in Idaho for demonstration purposes. Demonstration projects were held for six Corps Districts resulting in an average per project time and cost savings of 50 and 25 percent, respectively. [Installation Files, USAETL Annual Historical Summary for Calendar Year 1988, "Civil Works," unpaginated.[43]]

Manifold Corps uses

Potentially, one GPS station could supplant a hundred shore stations, and enable the Corps to do a better job of having work completed just as it wished. USAETL specialists also were writing computer programs and perfecting techniques to establish elevations for survey missions.

Finally, at TDL's Tactical Positioning Branch, USAETL scientists looked into the potential weapons applications for positioning by means of GPS, or a combination of GPS and inertial techniques. GPS, the "next utility," was proving to have manifold uses indeed. Looking ahead, the Survey Division of TDL made no secret of the fact that GPS might have some very promising point positioning applications for weaponry in open spaces.



Surveyors used Global Positioning System technology to remeasure Mount Rainier.

Good and getting better

In the here and now, however, there were only seven operational GPS satellites in orbit at the end of 1988, and the units had yet to be replaced by the more sophisticated "Block II" models that would come later. Still, USAETL's equipment was capable of detecting movement of about 3 millimeters if reference points and object points were within a few kilometers of each other. This was easily enough to awaken interest in expanding research into other applications, especially with the augmented satellite network due to come online.

But perhaps the clearest measure of that interest is that the operation, once run solo by Robertson at the beginning of this period, had six specialists hard at work by the end of 1988. GPS was a big part of USAETL's success story in the years 1984-1988, and would prove its value under fire a few years later.

3. INERTIAL TECHNIQUES IN SURVEY AND POINT POSITIONING

Even assuming (as some did in this period) that GPS would "overtake" and render obsolete many existing and evolving survey techniques, USAETL scientists would continue to create and refine new inertial and point positioning techniques. The eggs were not all in one basket.

Improvements in survey and point positioning

As is typical at USAETL, research efforts toward survey technique improvement took place on not one but many fronts. Some, such as GPS-based initiatives were high tech and sophisticated; others, such as improvements to data sets and equipment, were less striking but not less useful.

For example, 1984 saw not only the dam tilt mirror system, but also the report titled "*Test and Evaluation of Total Station Instruments*"[44] published by the Federal Geodetic Control Committee (FGCC). This report, prepared by USAETL for the FGCC's Instrument Subcommittee, gave instrument testing and data analysis results, and made it possible for the FGCC to determine geodetic specifications for their "*Standards and Specifications for Geodetic Control Networks*."[45] TDL researchers also prepared software, based on routines developed by the NGS, to permit surveyors to more easily transform station coordinates between the North American Datum of 1927 (NAD27) and 1983 (NAD83).

Research in the tradition of PADS (inertial methods)

One should keep in mind that, whatever the vast future promise of GPS-based systems, the Army still needed systems based on inertial technology. Only inertial technology could offer a capability for position, elevation and azimuth that was not subject to enemy electronic countermeasures. Also, in situations where the terrain had either a great deal of natural cover or dense urban architecture, GPS was still ill-suited. In such cases, inertial techniques looked to be useful for some years, and perhaps for still more years in "some sort of combination with GPS." [Interview with Richard Marth, Fort Belvoir, Va., 17 April 1991.[46]] Thus, the years 1984-1988 saw continued research into the refinement of inertial techniques, both in the directions of accuracy and economy.

During this period, USAETL also continued to develop technologies that had an immediate impact on the techniques of surveying. The fielding of PADS in 1984-1988 was only the first step in applying inertial technology to survey, and though USAETL's specialists kept an eye on PADS for possible ongoing refinements, they had options in mind as well.

PADS cut hours off the time needed to "survey-in" gun and missile emplacements. Making use of techniques derived from aircraft navigation, PADS used an inertial measuring unit (a level platform equipped with gyroscopes and accelerometers), a control and display unit, a data processing unit, and an independent power supply. These components enabled the PADS operator to determine his position and elevation on the basis of measuring motion relative to his coordinates at the start of a mission, and azimuth by defining the spin-axis of the earth.

In 1984, TDL's Survey Division tested new semiconductor technology capable of replacing PADS's magnetic core memory. After negotiating a new memory design, researchers had increased reliability 50 percent and cut $1,000 per unit while adapting the system to a new standard vehicle. The promise of PADS was quickly realized in artillery surveys, conducted by fewer people, yet completed nearly 10 times faster than before. PADS was an undeniable major success leading directly to further work in related areas at USAETL.

IPS, MAPS and other technologies

Following the very successful development of PADS, TDL scientists such as John Armistead began the 1984-1988 period exploring inertial surveying equipment capable of measuring horizontal and vertical coordinates with geodetic accuracies, determining gravity anomalies, and calculating gravity deflections of the vertical.

By the middle of the 1984-1988 period, TDL's Jack Perrin reduced the task at hand to "simply seeing what worked." [Interview with Jack Perrin, Fort Belvoir, Va., 28 May 1986.[47]] As was always the case at USAETL, this meant some projects proved to be dead ends, and some fell by the wayside having been overtaken by more promising approaches. Equally, there were some initiatives that bore fruit in the field.

A recounting of successes in the area of improved survey technique begins with the Inertial Positioning System (IPS) and the Rapid Geodetic Survey System (RGSS), both already in high gear during this time period. The former (IPS) was the Survey Division's answer to DMA's call for a PADS-related rapid method of getting horizontal positions and elevations for geodetic survey. The RGSS, in turn, involved modifying the IPS with upgraded software and an improved accelerometer to quickly measure gravity anomalies. Under the guidance of TDL's Edward Roof, the RGSS rounded into mature form in 1984.

Both the IPS and the RGSS were operated from trucks and helicopters, and both exceeded PADS in accuracy, measuring horizontal positions to within less than a meter and azimuths to within 20-arc seconds. Such position (and gravity) data helped DMA during this period to provide support to mobile missiles.

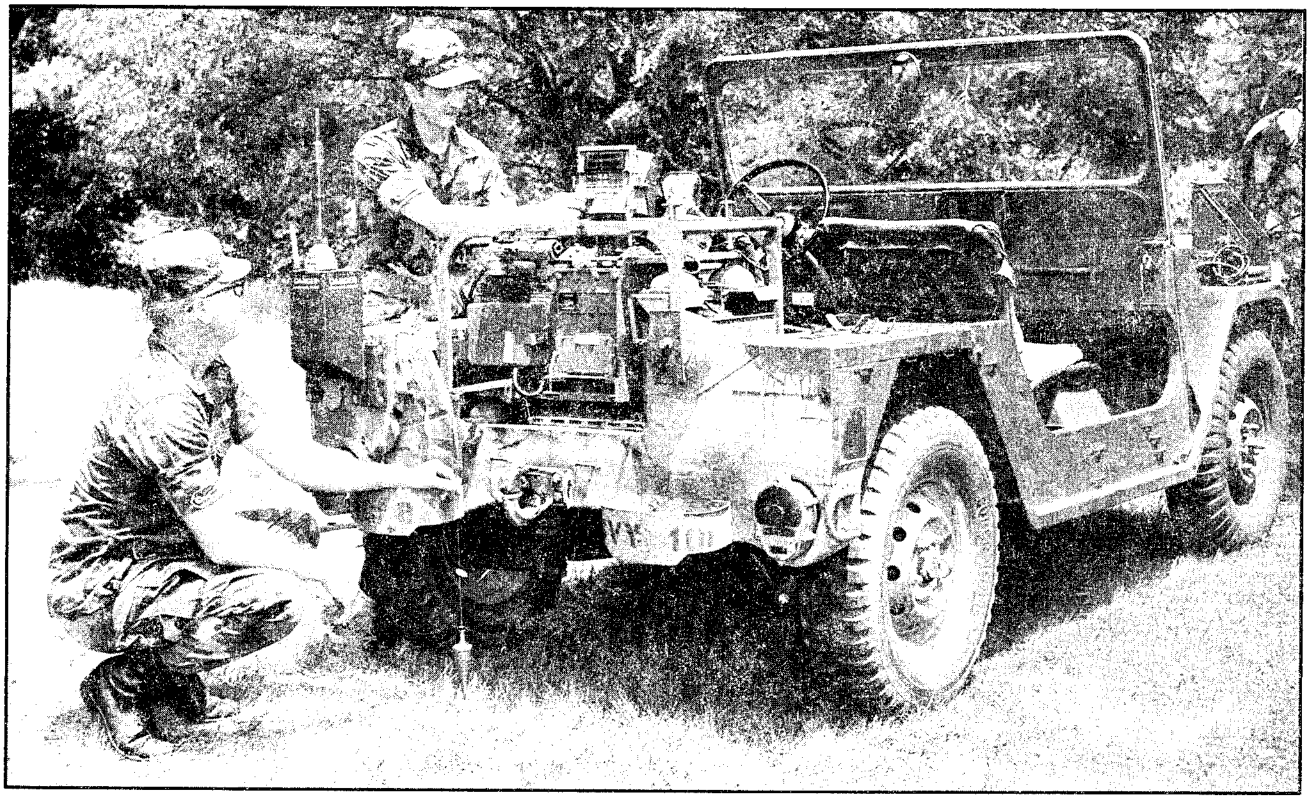
MAPS: Economy through standardization

As was the case in the formation of CAD (see page 3.), there often arose a need to standardize and, where possible, find the lowest common denominator (in the good sense) of support. In the case of survey, the Army needed to know the ideal specifications for a "generic" inertial survey device.

By 1984, it was clear that, left to their own devices, developers would produce many custom survey systems tailored only to their system's needs. Recognizing the prospects for waste and redundant research, the U.S. Army Materiel Command (AMC) gave USAETL the task of producing a uniform inertial survey device. This system, in turn, was to be compatible with the largest possible number of users requiring a certain level of point position accuracy.

Urgent need shown by 1973 Middle East War

At this point, it is useful to recall the background against which the press of research was taking place. The 1973 war between Israel and Egypt had stunned military observers with its pace of losses on both sides. With this, the famous "shoot and scoot" doctrine was born, as Gen. William DePuy (then-commander of the U.S. Army Training and Doctrine Command) drew



Position and Azimuth Determining System

some fateful conclusions from seeing how anything that had been seen in that war had been destroyed in short order.

Armor could "run" but too often "could not hide." In order to hide, they needed to have accurate — and very quick — notions of where they were and where they should go. For this, the field commander needed not only better terrain information but better point positioning as well.

But the question was: at what cost? The need for accurate point positioning, as crucial as it had proven to be, had to be balanced off against other needs — and all this against the background of a shrinking military budget. Could a cost-effective, generic system be distilled from the techniques perfected with PADS, IPS and RGSS?

Modular equipment for advanced inertial surveying

Army Under Secretary James R. Ambrose and AMC stressed the Army needed a humbler PADS, both cheaper and more generically applicable than the USAETL-developed system, and one that most weapons systems could carry onboard. In light of its extensive PADS experience, USAETL was the obvious choice to furnish the specifications, monitor the contracts and draw up the testing plans for what became the Modular Azimuth Position System (MAPS). [Interview with Peter Cervarich, Fort Belvoir, Va., 5 February 1992.[48]]

With this mandate, TDL's Frederick Gloeckler and David Thacker looked for ways to actually downgrade some of the laboratory's technology, albeit in a benign fashion. The goal was to cut the cost of development, logistics and maintenance. MAPS was intended to be a short-distance survey tool requiring less, not more precision than PADS. PADS would, said Cervarich, "bring the MAPS to the starting line, but then the MAPS would take over for the individual weapons." [Ibid.[49]]

The standardized positioning/orientation device at the heart of MAPS was called the Dynamic Reference Unit (DRU). The DRU was to provide onboard inertial survey capability for mobile weapons and sensors, including computing horizontal and vertical positions, attitudes and three-axis angular velocity.

But this system, in the interests of economy, had to fit the needs of many would-be users of inertial systems. USAETL researchers worked closely with the project manager of the Cannon Artillery Weapons Systems to ensure that the emerging standardized positioning/orientation device would work for a large number of different weapons and target acquisition systems. Conceptually, in 1985, this meant MAPS had to be able to support not only the M109/110 self-propelled

howitzers, but also the FIREFINDER counter-mortar/counter-artillery radars, and the Patriot missile.

MAPS methods

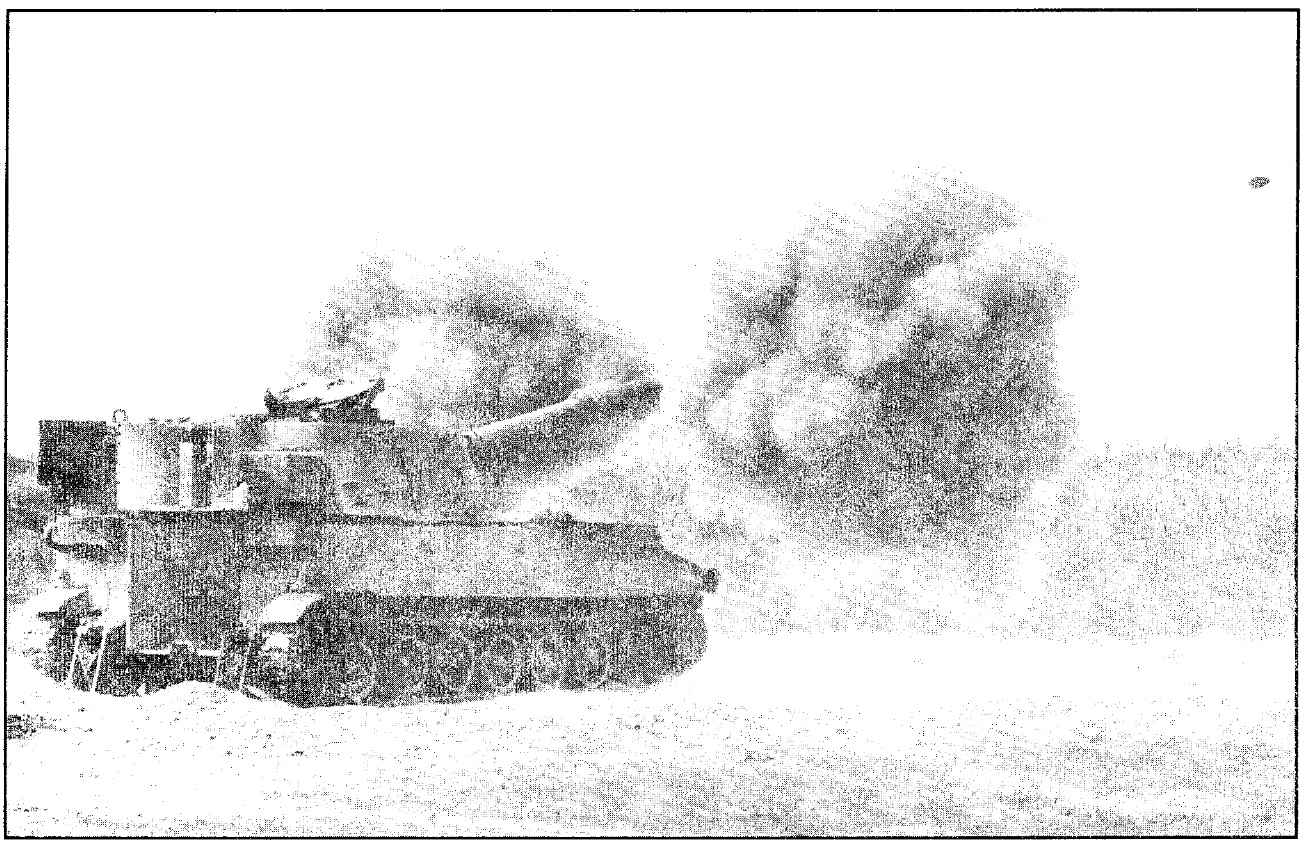
To that end, the initial research of Gloeckler and his team centered on improved microprocessor technology as a way to both cut cost and allow for the interchangeability essential to a modular, go-anywhere system. [Interview with Frederick Gloeckler, Fort Belvoir, Va., 12 January 1985.[50]] The MAPS team would work with the Project Manager-Paladin to assure maximum applicability.

MAPS was a technological breakthrough in a subtle sense of the word, in that it was in the best tradition of cost cutting and simplification that had always played a major role at USAETL. Much like the Environmental Design Guidance for Evaluation (see GSL section pages 30-49.), which sought to set cost-cutting environmental guidelines for design, or even CAD, which sought to define the minimum standard of DTD support, MAPS was seeking the lowest common workable denominator. Furthermore, USAETL engineers were quick to point out that "building down" to the best minimum system entailed fully as much hard work and inspiration as building up to the most complete one. In 1988, the survey specialists prepared the product specifications and helped with the contract package preparation and evaluation of the MAPS DRU for the howitzer improvement program.

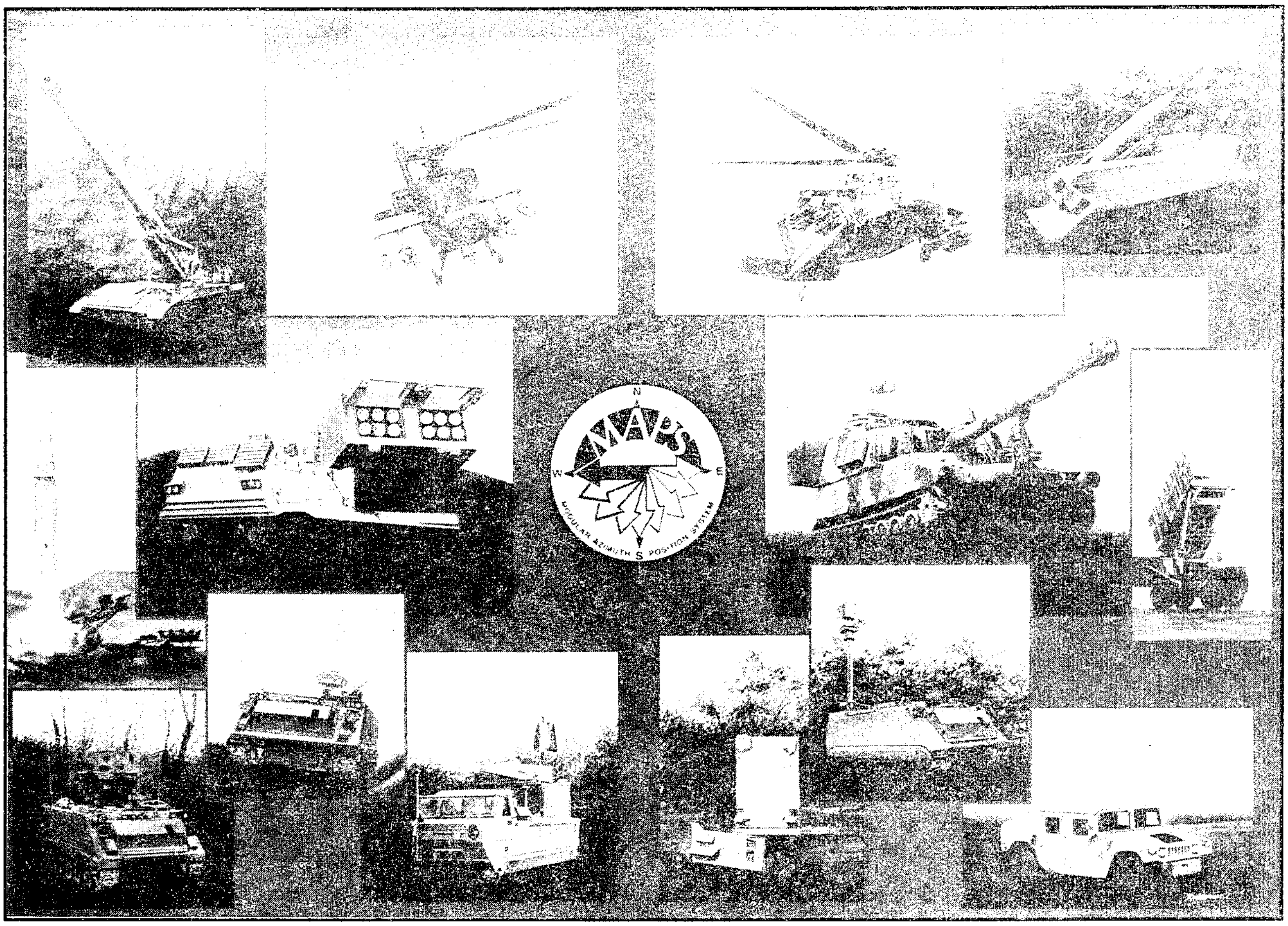
Toward a hybrid GPS-MAPS

An even more intriguing possibility at the period's end was the development of a "spin-off" hybrid combining MAPS with GPS for a unit not requiring a point of known control. Cervarich observed that the idea of such an inertial-satellite combination went "all the way back to the 1970s with Doppler technology" because it had such "obvious potential." In 1987, Survey Division scientists even put two connected systems in a vehicle in Fort Sill, Okla., and said "look what this could do if these were combined." [Interview with Peter Cervarich, Fort Belvoir, Va., 5 February 1992.[51]]

A combination of MAPS with GPS would allow the system to "optimize the availability of satellite signals" by using the satellite almanac in combination with the readings from the MAPS to be in the right place from the start. [Ibid.[52]] The hybrid also had the potential to exploit the respective advantages of the two systems, since GPS would not degrade with time or distance and the MAPS could not be jammed or blocked. Such a device was finally placed in a vehicle in September 1988. [*Army Research and Development Organization of the Year Report for FY88*, page 5.[53]]



The Modular Azimuth Position System had to have the capability to support the M109/110 self-propelled Howitzer.



MAPS had to support a variety of weapon systems.

Navigation systems

USAETL's expertise in the more sophisticated areas of inertial survey also was employed in looking for solutions to navigation problems. It was, after all, another aspect of the overall effort to get terrain information to the commander in the field. To that end, USAETL continuously monitored commercial-off-the-shelf technology (e.g., see QRMP), an effort that encompassed its search for a low-cost navigation system for the Army's many nonturreted wheeled vehicles.

The sheer number of the vehicles needing land navigators encouraged the use of technology less costly or complex than many existing USAETL-developed systems. Researchers turned to proven low-cost navigation methods, but judiciously augmented with digital data bases.

Low-cost map navigator

By the end of the 1984-1988 period, TDL scientists had explored a number of systems without settling on one that fully met the Army's requirements. The starting point, however, was the digital data base to be supplied by DMA. The researchers looked into ways to make use of either raster-type or vector-type digital data to provide the necessary map data base for a dead-reckoning navigator that was envisioned as a key part of the eventual system.

The goal was to fashion a computer-based system that yielded both direction, supplied by an electronic compass, and distance traversed, supplied by wheel sensors. At the end of the 1984-1988 period, USAETL engineers were assessing the merits of modifying a commercial navigator to a military format. They also were looking at a vector road data base with an eye toward adding off-road features. Given the availability of DMA 1:50,000-scale standard products, plans were made to let a contract to do the required modifications of the input-output functions.

4. LEGACY OF PERSHING II

Under the aegis of TDL's Special Projects Division, The Pershing II missile was completed and deployed at the start of the 1984-1988 period. The Pershing II initiative resulted in many commendations, and was a highly visible result of USAETL's work.

Indeed, the nonprofessional must be reminded of how a missile brokered away in 1987 in negotiations with the Soviets was much more than a bargaining chip. The Pershing II missile was a machine that could read maps, and a sophisticated robotic weapon of a whole new order. As such, it was of immense historic importance, no matter what its actual fate. The Pershing II demonstrated the feasibility of a new technology — a technology that made use of terrain data in new ways in a terminally guided missile. Such uses of terrain data were dramatic proof, not only of what might be done, but what *was* being done with a machine that could read maps.

Those maps, in turn, had to be "machine-readable" and supplied in advance to the machine. The supplier at the outset, and the cartographer setting the rules for what the map would include, was USAETL. Without the laboratories' work, the Pershing II may never have been, or at best, would have come on the scene far later. The "PII," as it was referred to around USAETL with pride, was an immense triumph for its scientists and a story worth retelling.

Synergy among scientists

President Jimmy Carter gave PII research the nation's highest defense priority designation (DX); a distinction it shared only with the XM1 tank and the M-X missile. This led directly to the Army's December 1983 acquisition of the first of a planned new generation of robotic weapon systems: the Pershing II missile. And certainly that project was a direct result of 10 years of high-priority research and development by USAETL engineers such as Donald Skala, John Pattie and Anthony Stoll. But it was just the beginning.

Any look at the funding or priorities of USAETL initiatives in the years 1984-1988 demonstrates the enormous significance of the research on reference scene generation and smart weapon technology in the preceding period. Indeed, in the year 1985, USAETL's total funds stood at $49.7m, only to climb to $104.5m by 1988 — all this in a period of tightening military budgets. Though much of the related, derivative work in this subsequent period was classified, the track record of USAETL's impressive success in this area of research is hard to miss.

Advanced weapon system support

Much of USAETL's growing program in 1984-1988 was devoted, directly or indirectly, to supporting the military's advanced weapon systems. MAPS and RGSS, for example, were developed to provide accurate survey to artillery and sophisticated missiles, respectively.

The creation of CAD, in turn, was aimed at providing some help in evaluating and defining the type of digital data that was going to be needed by such future Army systems. At the same time, the laboratories' researchers were working hard at developing techniques and equipment intended to ease the burden on DMA, whose daunting task included producing digital data bases required by advanced weapons, mission simulators, computerized command and control facilities, and others. Two examples of such pursuits in this period were the laboratory scientists working on advanced photogrammetric technology and those struggling with the complexities of automating feature extraction.

Though work proceeded on many fronts, USAETL research had a common goal in providing terrain information for weapons support. Even the continuing research into environmental effects on weapon systems must be seen as having an application to the effective development and deployment of weapon systems.

Weapon guidance support

In addition to their continued labors in the general area of weapon systems support, USAETL researchers continued to refine their successful applications of DTD to weapon support.

In large part because of their considerable expertise in working with computer processing techniques in combination with topographic data bases, USAETL's laboratories had been the logical choice to help develop so-called "correlation guidance systems" for the Pershing II missile. Such systems sought to provide a prepicture of what a missile was supposed to strike and correlate that scene with real-time radar imagery as the missile approached its target. Thus, reading its own "map," the missile could navigate itself to within meters of the precise center of the target.

Benefits of "smartness"

In the last few seconds before impact, the correlation guidance system corrected the missiles many times, and such gains in accuracy moved the military to take advantage of several corollary economies. With more accurate missiles, less bulky warheads were possible, and obviously, collateral damage and civilian losses might be minimized.

A second major plus that allowed some rethinking was the fact that making the missiles "smart" on the tail end of the flight allowed them to be less accurate at the front. Missile launchers could now be shifted around from location to location without suffering a loss of accuracy. Those launching the missile had a better chance at eluding return fire by "scooting" elsewhere.

Guidance near the target

Conventional ballistic missiles suffered problems with accuracy due to anything from launch variables to atmospheric buffeting. Corrections in flight had to be made by inertial guidance systems that were, in turn, dependent on the accuracy of survey. By contrast, the smart missile, though inertially guided at its launch, was designed to be taken over by terminal target correlation as it neared its target.

Originally, the smart missile designers thought of using an analog correlator on film as the prepicture; but as it turned out, the onboard computer used a digital topographic map stored in its memory with the image being "seen" by radar in the missile's nose cone. The end result, however, was the same: the missile calculated its own course adjustments, making many small adjustments in the last few seconds before impact.

Making digital data reference scenes

Before a "smart missile" could be smart and navigate to its target, it needed to know what to look for. Laboratory scientists had helped DMA define, create and evaluate an operational data base for use in reference scene generation. As stated, the answer proved to be a digital topographic map. This can hardly be surprising in view of USAETL's continual interest in the possible applications of DTD. At the beginning of the 1984-1988 period, the very time the Pershing II was starting to be deployed, another part of USAETL was completing a study of the likely customers for DTD.

The researchers also developed a data base plant reference scene-production facility which allowed DMA to generate reference scenes for preselected targets. This work also was completed with few hitches and no delays.

Source of pride

At the start of the 1984-1988 period, Col. Wintz took "personal pride" in seeing the USAETL-developed Reference Scene Generation Facility (RSGF) being deployed in support of the Pershing II missile. [*FY84 Laboratory of the Year Report*, page ii.[54]] The reasons for his pride, shared laboratory-wide, are not hard to understand. The PII was a major triumph of Col. Wintz's stewardship which ended roughly at the same time that the missile was deployed to Germany.

The PII RSGF culminated an intensive, 5-year development and test program for which USAETL had been responsible for all aspects of the development of the reference scene equipment, including system design and fabrication, hardware, software, configuration control, training, publications, provisioning, and engineering support. For all that, this extremely high-priority project was not only finished on time but within budget — and this despite 30 recorded engineering change orders. Support to the Pershing II missile program was completed in December 1985, when the PII achieved its Full Operating Capability.

USAETL support for the PII did not entirely end with deployment. Support for this phase of the project included equipment acceptance testing and the development and implementation of diagnostic test capabilities in tactical units deployed in Europe. [Installation Files, USAETL Annual Historical Summary for Calendar Year 1985, unpaginated.[55]]

Pointing toward new weaponry

The Pershing II missile was "brokered" away in landmark arms negotiations with the Soviets in 1987, but its story did not end there. As the first "smart" missile system, the PII had an importance that extended far beyond its geopolitical and tactical fate. It demonstrated conclusively the feasibility of smart, target correlation weaponry and pointed the way for other smart weapons to come. The three key technologies integrated were:

- Image Correlation
- Radar Mapping
- Digital Topographic Data Processing

At USAETL, where the smart working parts of the PII came into being, a continuing effort was undertaken to improve upon the technology that had made this breakthrough possible. To that end, the laboratories established a special facility to evaluate data bases and exploit data from advanced sensors.

The laboratories' hardware/software system served as an in-house test bed for data base and reference scene research, and continuously looked at the "quantity and quality" of the required reference scene data. [Interview with Richard Marth, Fort Belvoir, Va., 17 May 1991.[56]]

Benefiting other smart weapon systems

The equipment was upgraded to allow USAETL researchers to develop, manipulate, test and verify target data bases. In addition, work proceeded on how to better generate and modify synthetic reference scenes, as well as how to simulate weapon system correlation models.

Such research streamlined some of the steps in reference scene generation while seeking to standardize the requirements of a host of emerging systems. Such systems, while promising, were in danger of overwhelming DMA with their digital data requirements. USAETL researchers looked long and hard at existing and planned correlation guidance systems to identify

the specific data bases and reference scene requirements of each.

The aim of such a study was refining the techniques developed for the Pershing II, by developing a better data base and improving the content, accuracy and resolution of the reference scenes.

Pershing II achievement

For its legacy to a new generation of weapons, the Pershing II was a milestone achievement for the Army and USAETL. The target correlation techniques developed showed immediate benefits, not just for the Army, but for the entire military. Not surprisingly, the laboratories received a Corps award for excellence in 1985.

In addition, like so many projects at USAETL, the Pershing II also was a "force multiplier." With its 10 to 1 increase in accuracy, an analogous amount of firepower could be deleted from the warhead. And the savings on the Army's end would be matched by a reduction in collateral damage at the point of impact.

Hidden merit: Intimidation

But, in the last analysis, one should be especially careful not to overlook the intangibles of the "PII" success story. Quite apart from demonstrating the feasibility of DTD-supported target correlation technology, apart from the benefits of its uncanny accuracy, and even apart from the impressive dedication and efficiency of USAETL in completing the project on time and within budget, the Pershing II had a subtler but no less important historical significance. It had provided impressive, even intimidating, proof of "what the U.S. could do" when it wanted to. [Ibid.[57]] At least one scientist said that the PII was as important in its showcasing of our digital capabilities as it was as a machine of war. [Ibid.[58]] Stoll recalled the effect demonstrating those capabilities had on the Soviets:

"The Russians sat out there on their ships and watched the demonstrations from afar. They saw that the PII was very accurate. Quite simply, it made them afraid of us — and a lot of missile treaty negotiations resulted." [Interview with Anthony Stoll, Fort Belvoir, Va., 17 May 1991.[59]]

The implication was that Soviet research would have trouble coming up with a system to compete with the accuracy of the Pershing II. So it was that, without striking a single hostile target, the PII scored a subtle victory over a potential enemy.

Turning point

The Pershing II was yet another turning point in the "Digital Topographic Revolution." It used DTD to reorient itself. If, then, it was the first map-reading missile in a generation of "smart" weapons leading to the "brilliant" weapons of the 1990s, then it can be said that USAETL took pride in helping teach it to read and in supplying the text.

The legacy of the Pershing II, the emerging wide applications for GPS use, the fruitful possibilities for its combination with MAPS technology, and the whole new world of users opening to digital maps, made the outlook for TDL a bright one at the close of the 1984-1988 period.

Footnotes

1. Interview, author with Frank Capece, Fort Belvoir, Va., 26 November 1991.

2. "TEC to support simulation systems and programs for DTD exploitation," *Digital Data Digest*, Vol. 2, No. 1, Fall 1991, p. 2.

3. Briefing by Richard Herrmann, Fort Belvoir, Va., 26 January 1991.

4. Interview, author with Douglas Caldwell, Fort Belvoir, Va., 22 May 1991.

5. Interview, author with Frank Capece, Fort Belvoir, Va., 26 November 1991.

6. Capt. David Gallay, *Tech-Tran*, Vol. 6, No. 3, Summer 1981, p. 2.

7. Interview, author with Regis Orsinger, Fort Belvoir, Va., 1 July 1991.

8. Briefing by Richard Herrmann Fort Belvoir, Va., 11 January 1991.

9. *Digital Data Digest*, Vol. 1, No. 3, Winter 1991, p. 1.

10. Interview, author with Frank Capece, Fort Belvoir, Va., 14 October 1984.

11. "Charting a World of All-Digital Maps," *Defense*, 1988, p. 20.

12. Ibid., p. 21.

Footnotes, continued

13. Ibid.

14. Ibid.

15. *Digital Data Digest*, Vol. 1, No. 3, Winter 1991, pp. 1-2.

16. Interview, author with George Simcox, Fort Belvoir, Va., 11 January 1990.

17. Briefing by Richard Herrmann, Fort Belvoir, Va., 11 January 1991.

18. "Charting a World of All-Digital Maps," *Defense*, 1988, p. 22.

19. Interview, author with George Simcox, Fort Belvoir, Va., 3 March 1990.

20. Interview, author with Frank Capece, Fort Belvoir, Va., 26 November 1991.

21. Interview, author with Frank Capece, Fort Belvoir, Va., 26 November 1991.

22. *Army Tactical Digital Terrain Data Requirements Forecast* (ETL-SR-1), Fort Belvoir, Va., July 1987, p. vi.

23. Ibid.

24. Ibid., iv-x.

25. Ibid., viii.

26. Ibid., p. ix.

27. Ibid.

28. Interview, author with Regis Orsinger, Fort Belvoir, Va., 1 July 1991.

29. Interview, author with Frank Capece, Fort Belvoir, Va., 26 November 1991.

30. Ibid.

31. Ibid.

32. Interview, author with Regis Orsinger, Fort Belvoir, Va., 1 July 1991.

33. Interview, author with Kenneth Robertson, Fort Belvoir, Va., 3 October 1984.

34. Interview, author with Kenneth Robertson, Fort Belvoir, Va., 3 October 1984.

35. "Continuous Deformation Monitoring with GPS," paper presented at the 11-14 May 1988, American Society of Civil Engineers' Specialty Conference, "*GPS 88-Engineering Applications of GPS Satellite Surveying Technology*," p. 93.

36. Interview, author with Douglas Caldwell, Fort Belvoir, Va., 7 February 1991.

37. Interview, author with Stephen R. DeLoach, Fort Belvoir, Va., 6 May 1991.

38. "Continuous Deformation Monitoring with GPS," paper presented at the 11-14 May 1988, American Society of Civil Engineers' Specialty Conference, "*GPS 88-Engineering Applications of GPS Satellite Surveying Technology*," p. 99.

39. Ibid.

40. Capt. R.K. Burkard, *Geodesy for the Layman* (St. Louis: Aeronautical Chart Information Center, 1968), p. 1.

41. *Lab Lines*, Vol. 9, No. 5 (September/October 1988), p. 1.

42. Ibid.

43. Installation Files, USAETL Annual Historical Summary for Calendar Year 1988, "Civil Works," unpaginated.

44. "*Test and Evaluation of Total Station Instruments.*"

45. "*Standards and Specifications for Geodetic Control Networks.*"

46. Interview, author with Richard Marth, Fort Belvoir, Va., 17 April 1991.

47. Interview, author with Jack Perrin, Fort Belvoir, Va., 28 May 1986.

48. Interview, author with Peter Cervarich, Fort Belvoir, Va., 5 February 1992.

49. Ibid.

50. Interview, author with Frederick Gloeckler, Fort Belvoir, Va., 12 January 1985.

51. Interview, author with Peter Cervarich, Fort Belvoir, Va., 5 February 1992.

Footnotes, continued

52. Ibid.

53. *Army Research and Development Organization of the Year Report for FY88*, p. 5.

54. *FY84 Laboratory of the Year Report*, p. ii.

55. Installation Files, USAETL Annual Historical Summary for Calendar Year 1985, unpaginated.

56. Interview, author with Richard Marth, Fort Belvoir, Va., 17 May 1991.

57. Ibid.

58. Ibid.

59. Interview, author with Anthony Stoll, Fort Belvoir, Va., 17 May 1991.

Geographic Sciences Laboratory

Visualizing the battlefield for the soldier

In the introductory overview to this history, the observation was made that USAETL often works simultaneously on different approaches to the same problem. Nowhere was this more true than in the case of the Geographic Sciences Laboratory (GSL), where researchers looked for alternative ways to both acquire and impart terrain information to the commander in the field. Indeed, some of GSL's research in the 1984-1988 years had a somewhat different perspective of the "Digital Topographic Revolution" than the work being carried out at the Topographic Developments Laboratory (TDL), and its Concepts and Analysis Division (CAD).

Where much of the TDL and CAD work assumed, or sought to guarantee, the existence of adequate Digital Topographic Data (DTD) support, several of the initiatives in GSL relied on imagery-derived terrain data. Such data, in turn, even when rendered in digital form, communicated its information to the commander as imagery. It might have been enhanced, warped or manipulated in a number of ways, but it remained a bird's-eye image of what the commander needed. GSL worked on new ways to exploit aerial imagery, and in so doing, put itself at the heart of one of the more interesting debates taking place at USAETL in these years.

This was particularly true since the Digital Topographic Support System (DTSS) was under development in GSL during this period. DTSS was envisioned as exploiting DTD in an ever-increasing number of areas.

Imagery and DTD

Why was there a friendly debate during these years over how best to provide terrain information to the commander? Hugely simplified, the issue centered around two questions: 1) Was there an interim (or less costly, less laborious) way to provide commanders with adequate terrain information other than by using DTD? 2) Was there a danger that the required DTD might not be forthcoming in sufficient quantity, and, if not, what could be provided in the interim — or even instead?

Some GSL researchers leaned toward the affirmative on both of these questions. Both Douglas Caldwell, who worked on GSL's Electronic Map Data initiative during these years, and Daniel Edwards, who spearheaded work on the Terrain Information Extraction System (both discussed in this chapter), looked for other, usually simpler, ways to provide the necessary information to the commander. But the primary purpose of such work was to supplement DTD "where none existed."

At the same time, work on DTSS proceeded, based on the assumption that proper DTD would be available to support the system when fielded. That notwithstanding, looking into imagery-based mapping systems remained one of GSL's primary responsibilities. GSL specialists offered this line of research as an additional source of information that, though less informative than DTD, was likely to be more up-to-date.

GSL at a glance

Historically, GSL had carried out research and development in military geographic information (MGI), data generation systems and data visualization. In the 1984-1988 time frame the lab grew, expanding from two divisions to three. The 1983 MGI Data Processing and Products Division and the Land Combat Systems

GSL researchers worked to provide commanders with quick terrain graphics for better tactical knowledge of the battlefield.

Division were superseded by the Terrain Visualization Division, the Terrain Analysis and Data Generation Division, and the AirLand Battlefield Environment (ALBE) Division.

The Terrain Visualization Division improved the generation of computer images by combining various feature data with elevation data to fashion realistic 3-D battlefield scenes. USAETL researchers had long known that deciphering traditional maps often posed problems for the commander in the field, and that the ideal "map" would be much more (and less) than the standard mixture of busy lines and symbols.

The Terrain Analysis and Data Generation Division directed research to improve the production of digital topographic data bases. The abiding bottleneck at the Defense Mapping Agency (DMA), where hundreds of users were demanding DTD support, gave added urgency to this work.

The ALBE Division worked continuously on the ALBE Demonstration Test Bed, and studied and restudied the impact of environmental conditions on the battlefield, both on design and performance.

As always, however, there was more to it than a new division and some name changes at USAETL. GSL had two product-focused systems in development during the 1984-1988 years: the DTSS and the Quick Response Multicolor Printer (QRMP). Both were major breakthroughs in providing optimal terrain information, and neither was without promise for making things faster in the future as well.

A look at these two projects will confirm, however, that the "Digital Topographic Revolution" at TDL focused heavily on the terrain products during this period.

1. DTD IN THE FIELD: DTSS

Among the major focuses at USAETL during this period was continuing development of the long-awaited Digital Topographic Support System (DTSS). In providing the field commander with quick terrain graphics for better tactical knowledge of the battlefield, DTSS will provide the kind of "force multiplier" the Army has long sought, something to make up for a potential mismatch in military manpower. Faced with the chaos of battle, the field commander with DTSS has access to terrain products that are not only more up-to-date, but more intelligible as well, from a partially automated terrain data system.

GSL scientists came to envision a host of application modes for DTSS, but they all grew out of one initial purpose: to provide faster and better terrain analyst input into the Intelligence Preparation of the Battlefield. The speed and flexibility lent by automation would go to work for the terrain analyst. Many complicated algorithms and expert systems went into explaining DTSS within the laboratory community; but to the layman, it could simply be seen as another USAETL initiative seeking to give the Army commander "the edge."

Using DTD

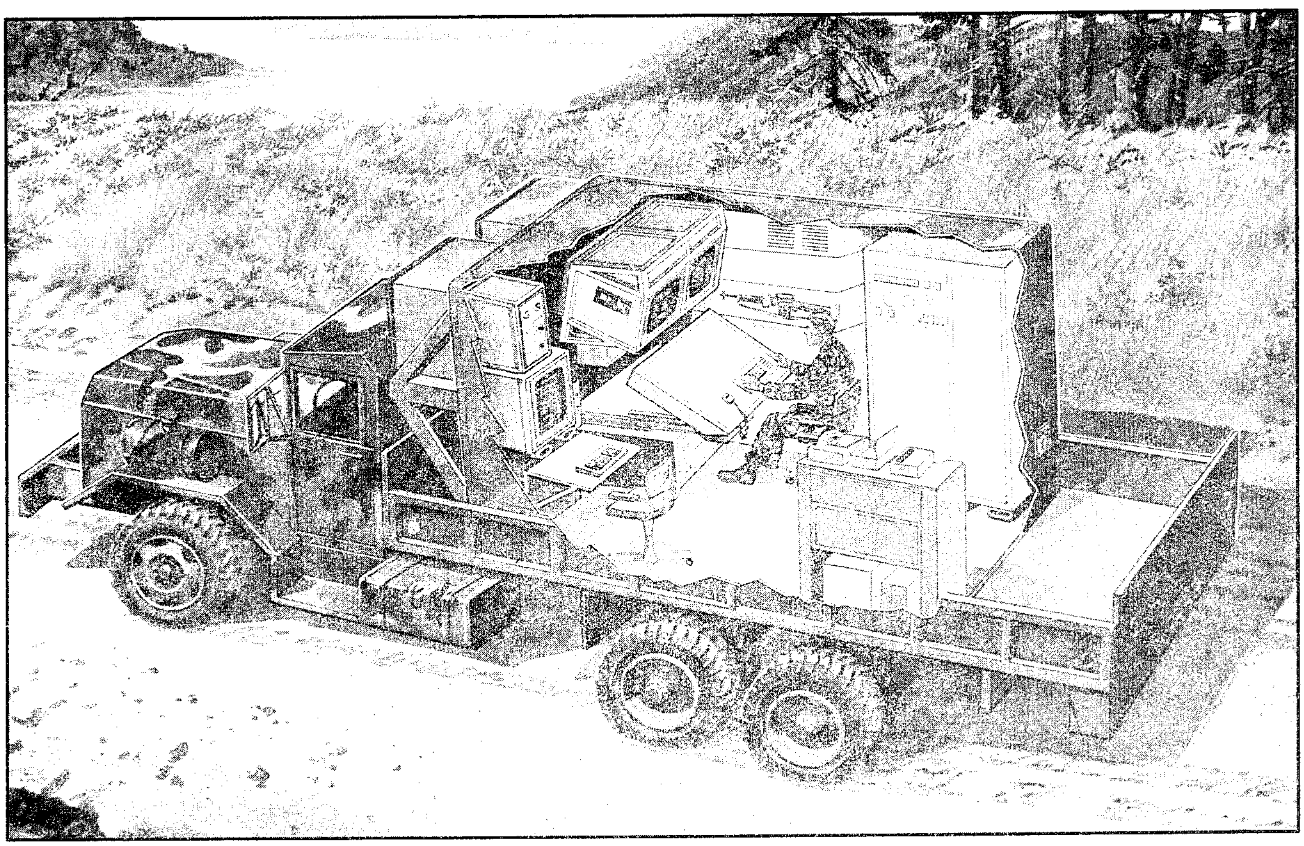
The idea behind this research was to provide Army terrain teams with a system capable of using DTD to generate tactical terrain graphics. The major inputs to DTSS were to be the standard digital topographic data bases produced by DMA, including Digital Terrain Elevation Data (DTED) Levels 1 and 2, Interim Terrain Data and Tactical Terrain Data.

Elsewhere, specifically at TDL's Concepts and Analysis Division (CAD), scientists were working to ensure that such data would be available, both in sufficient quantity and in sufficient detail, to support DTSS and related systems. Thus, USAETL was involved at both ends of the process.

Better map

The "map" provided by DTSS improved upon the unwieldy, confusing and outdated manual paper products of the past. Though the DTSS product presented much of the same information, it was a more versatile, consistent product, and could be created faster. [Keith Kurtz, Memorandum to TDL Director, Fort Belvoir, Va., 19 May 1992.[1]] Whole new technologies were required to bring DTSS into being. Indeed, the information provided by DTSS went well beyond providing up-to-date locations (essential though that is), to giving vital data including cross-country mobility and intervisibility.

The aim of the digital revolution in the field was to make command decisions truly informed ones, based on MGI of a new order. It was to be a new kind of map called a Tactical Decision Aid. It was to be born of a system that would supplant the arduous manual methods still used in the field to store, process and analyze terrain data.



Digital Topographic Support System

Enhancements en route

But being able to do this did not happen all at once. The DTSS was to be continually refined throughout the 1984-1988 period to take advantage of the latest electronic data processing techniques and computer graphics technology. USAETL scientists worked to incorporate commercial graphics software systems, existing terrain analysis software, newly developed software, and various commercial computers and peripheral devices. [Ibid.[2]] And even before that, the mere idea of the eventual DTSS underwent a number of changes, fits and starts. DTSS, as it came to be seen at the end of the period, is part of a story that requires going back a few years into USAETL's past.

Uses of terrain

The story of the development of DTSS is a long one, going all the way back to World War II. At that time, as the mobility of the field forces began to outpace the commander's knowledge of the battlefield, the Army became increasingly aware of a pressing need for precise, up-to-date maps. In the postwar years, with more mobile equipment coming on-line, the perceived gap only got worse.

The first clues came from the Arab-Israeli War of 1973, when both Egyptian and Israeli armored units paid a terrible price for their inability to make good use of terrain. From that point in time, the doctrine of "shoot and scoot" to safe terrain gained new favor throughout the Army community. But employing this doctrine required much better terrain information.

Topographic Support System

USAETL documents cite studies sponsored by the Combat Developments Command during the mid-1960s as forming the basis for early topographical developments. [DTSS Historical Facts, In-house Document, Installation Files, 17 October 1990, page 2.[3]] The resulting studies led to the Topographic Support System (TSS) Required Operational Capability (ROC) document in 1976.

Period of uncertainty

The first impetus toward finding a long-term solution to the topographic support dilemma came from within USAETL in GSL. Here, the "Army Terrain Information System" (ARTINS), though only sporadically funded from 1971 to 1978, laid the theoretical groundwork for DTSS. ARTINS placed emphasis on developmental solutions to the topographical support problem.

After ARTINS was "zeroed" in 1977, USAETL made a critical decision to turn this setback into a long-term gain. Following a crucial meeting of Army planners at Fort Huachuca, Ariz., in 1978, ARTINS would be renamed DTSS.

However, there were technological problems to solve, and the funding support had to be found for that research and development. The unavailability of terrain data was a huge hurdle. USAETL had to demonstrate the value of automating the terrain analysis process for greater quality and productivity.

Tech base investment in the future

USAETL had a two-front plan of attack to demonstrate the feasibility of DTSS. First, USAETL decided to develop a laboratory prototype, called the Digital Terrain Analysis Station (DTAS) as a "tech base investment in the future." Second, the scientists undertook initiatives to show how such technology could have a place in field operations. The Field Exploitation of Elevation Data (FEED) demonstrator took to the road as part of this education and selling program, showing that digital data could do things a paper map could not. The Demonstration System (DEMONS), a digital image analysis demonstrator was used in this context as well.

DTD requirements study

In 1983, the Terrain Information Systems Group (TISG), initially under Regis Orsinger, and later Frank Capece, began an evaluation of two DMA prototype data bases that grew into the Digital Topographic Data Requirements Study of 1984 (This is explained in greater detail in the TDL section). Orsinger called this "one of the most important activities undertaken by USAETL in these years," in part because it highlighted the requirements of DTSS and similar emerging systems. [Interview with Regis Orsinger, Fort Belvoir, Va., 1 July 1991.[4]]

The appetite for DTD was mushrooming in three areas: Army terrain analysis, Army analysis community needs (such as modeling, simulation, and training), and the tactical systems and programs such as smart missile guidance. Systems were being designed and built without regard to whether DTD would be made available to support such systems. There were twin problems here: the likely wasteful duplication of effort in different systems; and, finally, the size of the work load being laid on DMA.

The DTD study offered a four-volume, 700-page document identifying 75 Army systems that either required or anticipated a requirement for DTD. The count included 31 tactical systems, 26 systems or programs for simulation, training, test and development, and 18 systems for the analysis community. In many of these areas, Capece's team found the availability of data a real "problem area." [Interview with Frank Capece, Fort Belvoir, Va., 14 October 1984.[5]]

Following the DTD study, DTSS was kept squarely within the bounds of the data which were likely to be available to support it. The boundaries had been set, not just for DTSS, but for a host of emerging systems. In addition, TDL's own CAD would be formed to police requests for DTD to assure that requests remained reasonable and not redundant. Because the DTD study is regarded by many as one of the signal achievements of the 1980s, it is discussed in a number of places in this history, especially with regard to the formation of the DTD oversight element at TDL. That element, beginning as CAD within TDL, arose directly as a result of the crucial DTD study.

DTSS development

With the completion of the requirements study, attention returned to the DTSS development. Although significant funding was not forthcoming initially, there were enough funds to begin preparation of the documentation required for an Army life-cycle development program. This work still was being done by the TISG and subsequently by the Geographic Systems Development Division.

Although the 1984-88 period, on the whole, was marked with resounding successes for the DTSS program, it surely could not be considered "smooth sailing." The early period was characterized by changes in higher level Army management responsibilities. However, stable funding was established in 1986, which also marked the end of the management "merry-go-round."

Throughout the early and mid-1980s, DTSS program management at Army-level suffered through an identity crisis. For four consecutive years, the Army management chain of command changed, with the new boss changing directions each time. It was a period of two steps forward, one step back.

The major command for the development of the DTSS gap was the U.S. Army Materiel Command (AMC). In 1988, Harold Britton became the Program Manager (PM) for the program at USAETL. Responsibility for managing the development program was delegated to AMC's U.S. Army Communications — Electronics Command (CECOM).

However, there was redirection during this period. The initial DTSS Acquisition Strategy included a provision to share common hardware with the ASAS program. CECOM felt that hardware common to one of their programs, Joint Surveillance and Target Attack Radar System, should be used instead. The program was set back 5 months while studies were conducted to determine which hardware was best suited for DTSS. In the end, the ASAS hardware was selected and the DTSS AS was approved.

In FY86, AMC reassigned the DTSS program to the U.S. Army Troop Support Command (TROSCOM). The rationale was that most Army engineer systems were managed through TROSCOM. Unfortunately, unfamiliarity with electronics systems like DTSS caused TROSCOM personnel to attempt major changes that required Capece's team to revamp the already approved AS. While Capece was cooperating, he also was looking for another sponsor. Also, USAETL was working on a contract package, since the budget and schedule called for a contract to be let in late-FY86.

During this time frame, Brig. Gen. William Harmon became the Project Manager-Joint Tactical Fusion. He was responsible for development of ASAS and other Intelligence programs. A strong champion of Army topography and USAETL from his days as the commander of the 525th Military Intelligence Group at Fort Bragg, N.C., the general believed DTSS was critical to the ASAS program. He became concerned about the direction the DTSS program was taking under TROSCOM and, offered to take over management responsibility of the program. On 28 July 1986, Lt. Gen. Riscassi in the Office of the Deputy Chief of Staff for Operations and Plans assigned the DTSS program to Brig. Gen. Harmon.

Certain things had to be accomplished before DTSS could go under contract. First, a Required Operational Capability (ROC) had to be approved and an alphabet soup of documents such as Test and Evaluation Master Plan, Integrated Logistics Support Plan, Computer Resources Management Plan, Acquisition Plan, etc., had to be prepared. Then, a contract package had to be prepared and coordinated with various organizations. After that, the contract could "go on the street" for bidding. Finally, a Source Selection Board had to choose the best offer. This process would normally take 2 years, but Brig. Gen. Harmon wanted action and was willing to take the risks.

Fortunately, USAETL had been working on most of these documents already, in the event that a changeover in management would occur. Brig. Gen. Harmon authorized USAETL to go on the street with the contract package prior to approval of the ROC. Concurrently then, USAETL was working the approval process for these required documents while also soliciting bids from contractors. There was some risk, but, if successful, a year could be saved in development. In the end, all the pieces fell together. The ROC was approved and the contract was awarded on 29 July 1987, just 1 year after going under Brig. Gen. Harmon's management.

Much of this contract proposal review process was new to USAETL, since fully competitive contracts of this magnitude had not been managed by USAETL previously. Thomas Jorgensen headed the Source Selection Board made up of many bidders and many people from various organizations on the board.

Many DTSS team members spent June 1987 in Fort Hood, Texas, supporting the user evaluation of the

ASAS hardware. Prototype DTSS software was used, since ASAS software was not ready yet. The DTSS software worked and the users were satisfied with the ASAS hardware. It was an important milestone for the ASAS program, and Brig. Gen. Harmon greatly appreciated USAETL's support.

As it turned out, the awarding of the DTSS contract was only the beginning of another set of new experiences for the USAETL team. Now, another set of alphabet soup meetings and documents had to be dealt with, such as Critical Design Reviews, Preliminary Design Reviews, Computer Software Configuration Items, 2167A, a Department of Defense software documentation regulation, Engineer Change Proposals, etc. The next year was devoted to getting the contract on the right footing for the anticipated fielding of DTSS in the early 1990s.

2. REPRODUCTION IN THE FIELD: QRMP

Much like DMA, with whom it retained traditional ties, USAETL was swept up by the "Digital Topographic Revolution" in the mid-to-late 1980s. Among other things, this meant that traditional hard-copy maps were to be phased out, and when possible, near-real-time, highly versatile (and highly manipulable) digital products phased in.

Mapmaking bottleneck

Map availability has always been a serious bottleneck for military commanders, slowing their ability to make decisions and launch new operations. First, there was the mapmaking process itself, involving the laborious gathering of information, and the equally laborious process of sorting it all out and turning it into a comprehensible map. The latter step requires, in turn, some expert judgment as to what gets included and excluded. The skill, to say nothing of the patience, required in these steps is invariably an eye-opener to the nonprofessional who has long taken maps for granted.

The mapmaking process remained a stubborn problem, but especially so when one sought to reduce it to expert systems for a computer. Accordingly, initiatives toward automating the process of hard-copy map production were less stressed in the 1984-1988 period. This occurred, in part because of the turn to digital products, but one suspects also there was a recognition there was more critical work to do. Again, in the words of GSL's Caldwell, "the focus turned from the process to the product." [Interview with Douglas Caldwell, Fort Belvoir, Va., 22 May 1991.[6]]

Mapmaking had been an abiding bottleneck in the period 1979-1983, and it remained one, whether in digital or hard-copy form, in the years 1984-1988. Improvements had been made, and certain technological shortcuts had been found within these very laboratories, but few USAETL scientists in the period gave the impression that the problem was near being fully solved.

Military dimension

Mapmaking for the military took on an added dimension. Typically, the military user operates in great urgency, and with a need for even more precision and currency. Getting terrain information to the commander in the field is what the Army tacticians called a "force multiplier," helping to make every bit of firepower count and minimizing losses for the new, highly mobile Army.

Having up-to-date, precise terrain information is no mere convenience, nor is it merely a tactical plus; the whole direction of research and development at USAETL in the years 1984-1988 demonstrated clearly that terrain information had become a must-have factor in modern "shoot and scoot" warfare.

GSL researchers, along with others at USAETL, toiled away at aspects of the overall mapping bottleneck problem. One of these aspects was the bottleneck experienced in the art of map reproduction. In this area, USAETL scientists hoped to develop a new map reproduction technology which they envisioned as the "first significant advance in combat map reproduction since World War II." [USAETL in-house QRMP document, unpaginated.[7]]

New kind of map reproduction

Traditional map reproduction processes required using 27 people working a full 8 hours to turn out a single multicolor map. For the "modern, fast-paced battlefield," this was simply too many people working too long. And time was "precisely what the field commander would not have when maps are needed and the troops are waiting." [Ibid.[8]]

Yet, the usual printing press, once set up, could churn out a host of maps, and had been the time-honored method of providing terrain information. Nor could one dispute the necessity of having such maps. But was there a faster way to get things underway? More than that, was there a way to get a small-run product that did not require the huge expenditure of time and personnel associated with traditional battlefield map reproduction? Keeping a sharp eye on commercial technical developments, USAETL scientists seized on commercial xerographic techniques as an obvious possibility.

Xerography for the battlefield

In 1978, USAETL awarded a contract to Xerox Corp. for the feasibility study of what came to be called the Quick Response Multicolor Printer (QRMP), and a positive report with a preliminary design appeared in 1980. Despite numerous funding delays from 1981-1983, a working prototype was operational by the start of the 1984-1988 time frame. William Clark and his laboratory specialists had refused to let go of a possible way to do something about one aspect of the mapmaking backlog.

The idea was to combine color xerographic state-of-the-art techniques with laser technology in a dry copying process. But, by definition, the result had to be as high resolution as that of the traditional method, i.e., suitable for map and graphic productions. The major advantage was to be the capability for producing small runs of full-color maps in a short time, and the physical unobtrusiveness of the system itself.

New product

The QRMP did many things faster than the traditional methods. The QRMP made it possible for the field commander to have something that had not been available before: a limited-quantity, high-resolution terrain product. In other words, it was now practical to run off maps or graphics that would have been prohibitively expensive and time-consuming via the old technology. In short, the field commander had a terrain product in hand that he would not have had at all before.

QRMP capabilities

The QRMP that emerged from this research could produce up to 71 multicolor or 212 monochrome copies per hour. These copies, in turn, could be made from color or black-and-white originals as large as 24 inches by 30 inches (maps were seldom in the standard sizes suitable for copying machines). The QRMP also made it possible to overprint new information onto existing maps, or to print updated maps to show operational orders, order of battle or supplementary photographs as additions to the basic map. As a further mark of versatility, the machine also could copy transparent overlays.

All these capabilities came in a remarkably small package. The QRMP was to be housed in a militarized shelter which was suitable for transporting by a standard Army 5-ton truck, thereby eliminating the big, visible presence of tons of semitrailers crammed with soldiers from topographic units. Given the capabilities of the modern surveillance techniques available to the enemy, reducing the visible "signature" of command was a major plus. The smaller the better, and the quicker the better. The QRMP offered both.

Designing the QRMP

For a time, sporadic funding meant that in order for the QRMP to be up and running for incorporation with DTSS, laboratory engineers would have to put off ruggedizing the QRMP for the battlefield until later. Clark and his team worked on meeting the targeted reproductive standards in a laboratory environment.

In 1984, however, conventional support to the Army through AMC had undergone a change that profoundly effected funding for both QRMP and DTSS. Both projects became the programming responsibility of AMC major subordinate commands. This resulted, in USAETL's commander Col. Edward K. Wintz's words, in a very welcome "increased visibility, priority and funding." That, plus diplomacy, expertise, and plain hard work by USAETL scientists and engineers, had the QRMP back on track. [*FY84 Laboratory of the Year Report*, page i.[9]]

Soon, GSL could point to ongoing improvements made along the way, including, for example, the incorporation of four separate processes on one drum in 1984. Early in 1985, Development Test I and Operational Test I for an advanced operational model QRMP were successfully completed.

Successful tests in the field

This advanced development model already had all the basic capabilities planned for the fielded version except the digital interface. The Army Armor and Engineer Board conducted 3-week tests which showed that soldiers could operate the printer without difficulty. More than 12,000 copies of various terrain products were produced. [*FY85 U.S. Army Laboratory of the Year Report*, page 15.[10]] Not surprisingly, the ROC document was approved in December 1986, and a Full-Scale Engineering Development (FSED) contract was awarded in April 1988.

Into the development phase

In the latter part of the 1984-1988 period, the QRMP remained on schedule. The plan was for the QRMP to be fielded and mounted on a 5-ton truck by FY96. This was, however, a full 5 years later than the FY91 goal of Col. Wintz in 1984. [*FY84 Laboratory of the Year Report*, page 6.[11]] That, however, had its bright side, allowing GSL's researchers to reassess the project's components in the light of evolving commercial technology. Eventually (though well after the concluding year of this study), some cost saving would result from incorporating different, modified commercial-off-the-shelf equipment into a QRMP prototype.

Laser scanner a key addition

Unlike conventional lithographic presses, the QRMP used a dry printing process similar to that employed by the best commercial copiers of the day. But the addition of a laser scanner played a key role in improving the "dry" copying process to the point where it could meet the extremely high-resolution requirements of map reproduction. It was this combination of laser technology, with which laboratory scientists were familiar, and the latest color xerographic techniques that made the QRMP work faster than traditional methods.

Swifter system

The QRMP was envisioned as a fast, cost-effective, topographic reproduction system for the Army. When fielded, it was to produce multicolor topographic maps from hard-copy originals and digital data — and to do so "with the speed and accuracy needed to support combat operations." [USAETL in-house QRMP flier, unpaginated.[12]]

By 1987, the QRMP had evolved far enough that, following a 30-minute warm-up period, the system could turn out a full-color, full-size (20-inch by 30-inch) graphic in less than 5 minutes. Additional copies came even faster, at 1-minute intervals, undergoing only one pass through the printer. This, again, contrasted with an 8-hour wait for a single-color product from a field press. The QRMP could produce 75 full-color or 225 single-color products of lithographic printing quality.

Whole family of uses

USAETL's Dr. Kenneth Kothe, who retired during the QRMP research period, had foreseen "a whole family of uses" for the system. [Interview with Dr. Kenneth Kothe, Fort Belvoir, Va., 11 October 1984.[13]] Indeed, in addition to copying single and full-color graphics, the QRMP also was designed to produce transparent overlays for already existing maps, while also incorporating the capability of performing overprinting onto conventional maps. On the whole, USAETL saw this piece of equipment "revolutionizing tactical topographic reproduction capabilities." [*Army Research and Development Organization of the Year Report for FY88*, page 11.[14]]

An answer for right now

Sporadic funding in the early part of the 1984-1988 time frame, raised the possibility that the QRMP would be eventually technologically "overtaken," but for the field commander, who needed what was possible and needed it right now, QRMP was a sensible direction to go. It promised to provide fast, low-volume, color maps, graphics, and special maps such as intelligence and operations maps. Whatever already was known could now be disseminated quickly. Moreover, the QRMP promised to eliminate the need for hundreds of topographic unit semitrailers. Plans for incorporating a digital interface, in turn, promised to give the QRMP an even longer usefulness.

In getting quality terrain information quickly to the commander in the field, the QRMP unplugged one bottleneck in the flow of terrain information to the field. Too often in the past, information about the terrain could not be portrayed and reproduced in time to be helpful.

Furthermore, the QRMP was another example of USAETL scientists seeing a military use for evolving commercial technology. Though the color xerography techniques being prepared for the marketplace would later prove too costly, laboratory researchers were able to turn a commercial product into what was required. In so doing, USAETL continued its tradition of not only inventing new systems, but also scanning the market for emerging technologies. In so doing, the military could save both time and money otherwise required for research and development.

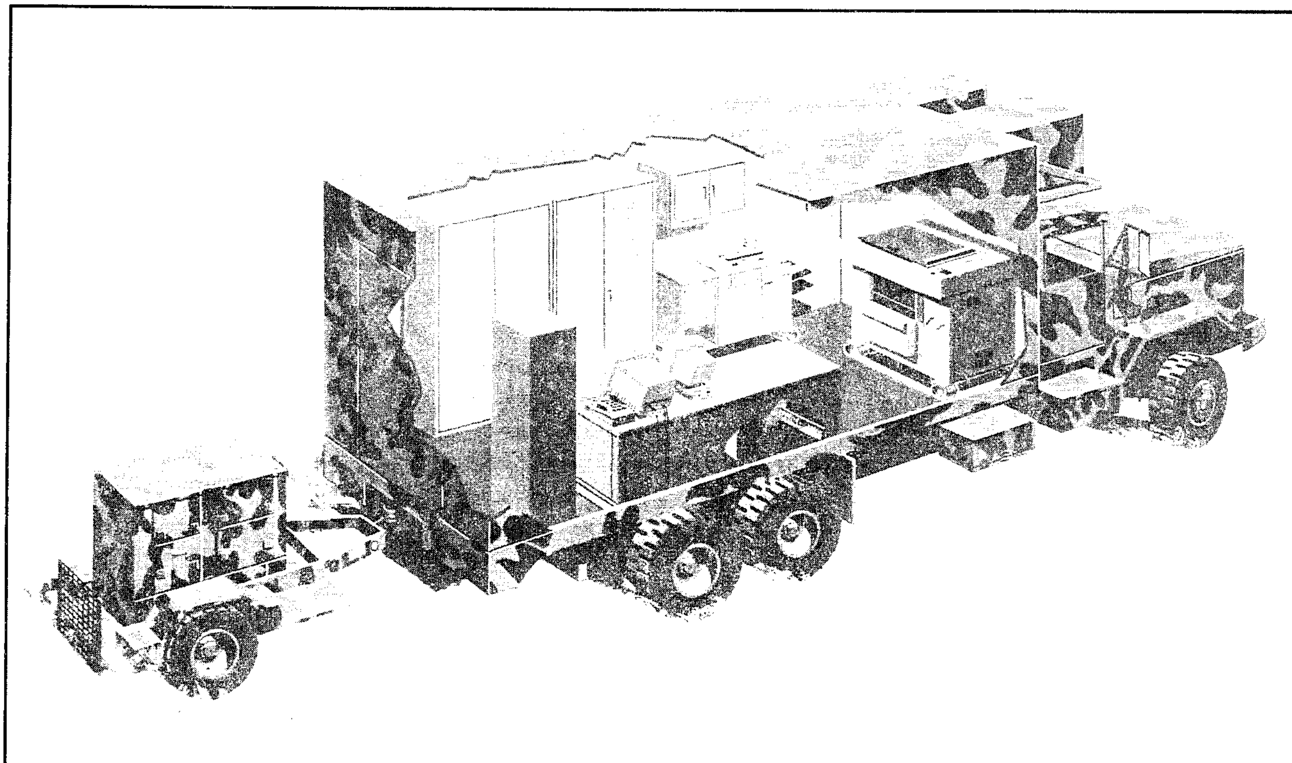
3. EXPLOITING ENVIRONMENTAL EFFECTS IN THE BATTLEFIELD

The U.S. Army had the unusual burden of having to be able to fight in almost every environment on Earth. But those who designed military materiel were sometimes inclined to take the environment for granted. Whenever it was considered, environmental variables were vague, mathematical factors, and emphasis was placed on how materiel performed in a closed, controlled environment. To the commander in the real world, however, this might result in operational problems with the product being developed, and an inoperable system was as good as none at all.

The Army's global theater of operations included damp tropical jungles, frozen arctic tundra and hot, dry deserts. Indeed, in Grenada and Panama the lesson hit home that no fight takes place in a laboratory. In GSL, as elsewhere in USAETL during the years 1984-1988, research had very close ties to events.

Compared to some of USAETL's other pursuits in 1984-1988, the goals of the environmental specialists at GSL addressed some fairly down-to-earth concerns. They were seeking to identify and publicize the effects of environmental conditions on Anny materiel. In addition, they were looking for the least expensive way to design, test, store, issue and use that materiel.

Yet, as different as this may seem from digital data work, for example, in a sense the Battlefield Environmental Effects Group was doing for materiel



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what CAD in TDL was doing for digital terrain data: seeking the lowest common denominator of low-cost and best performance in a standardized product.

Background

Environmental specialists had not always felt so much in tune with USAETL's mission. At the beginning of the 1980s, environmental specialists still considered themselves to be little more than "interested bystanders" at the laboratories. [Interview with Paul Krause, Fort Belvoir, Va., 5 February 1985.[15]] But by the latter part of the decade, these scientists were playing a key role in putting environmental effects to work in both battle planning and product design.

The years 1984-1988 saw this element in GSL come of age as a vital contributor to the Terrain Analyst Work Station (TAWS), and thus, the eventual fielded DTSS and, in turn, the Army's ASAS. Understanding the story, however, requires going back into the late 1970s.

Spur from computers

USAETL's current environmental initiatives find their origin in a response to a request from the Defense Mapping School in 1979. The school had requested weather effects slides and handouts for some courses, and the idea arose to add a few computer effects to the agenda. This was so successful that laboratory specialists began incorporating some of the same features at USAETL. Subsequently, James Beck, an official in the Office of the Army's Assistant Chief of Staff, got wind of this computerized environmental effects capability and set up a briefing in 1981. More briefings followed, and the Gallant Knight exercises in 1983 demonstrated what could be done with computers set up to evaluate environmental effects. [Interview with Paul Krause, Fort Belvoir, Va., 5 February 1985.[16]] As a side issue, the BEES also was used to estimate the speed of road movement for newly repaired roads for the Corps of Engineers, spurring support for automated terrain analysis by the combat engineer.

Tied into MICROFIX in 1986

By 1982, GSL's Battlefield Environmental Effects Software (BEES) had been developed. It took the purchase of new hardware and a 60 percent jump in software capability in 1984 to allow the conversion of part of the system to tie into MICROFIX (an Army microcomputer used by topographic units in the field).

By 1986, BEES was giving MICROFIX the ability to provide the intelligence community with an immediate capability to evaluate the environment. This integration would stimulate researchers to further develop software and data base content to improve MICROFIX in an evolutionary manner. [*Army Research and Development Organization of the Year Report for FY88*, page 11.[17]]

Tighter standards for more sensitive weaponry

This software development work was occurring at a time when weapon systems were becoming increasingly expensive and sophisticated. GSL researchers knew that such systems were likely to be more, rather than less, sensitive to the environment, "making the identification and application of realistic environmental criteria an even more important part of the materiel acquisition process." [*1991 Organizational Activities*, GSL, page 1.[18]]

USAETL researchers recognized this as a "major undertaking," for military equipment had to work in rugged circumstances under a variety of climates and conditions. [Ibid.[19]] They recognized that, on one hand, it would be wasteful and expensive to design every piece of equipment so that it would function under the most extreme conditions found anywhere on Earth. On the other hand, they wanted to provide guidelines to ensure that equipment could withstand the environment in which it was likely to be used. In short, they sought a rational basis for selecting environmental design criteria.

Focus of research

For the most part, the scientists were preoccupied with the frequency and distribution of natural battlefield obscurants (e.g., fog), improving the technology base of information about environmental effects on materiel (i.e., building a computer data bank and making it accessible), finishing up a glossary of environmental terms (i.e., getting everyone to speak the same language), and nailing down the relationships between environmental factors and materiel design problems. (see Environmental Design Guidance for Evaluation, p. 41.)

Specifically, USAETL specialists focused on continually improving methods for presenting climatological and geographical data. Getting the information was one thing, but disseminating it was another. Useful and rational criteria had to be rendered into convenient-to-use form. Scientists investigated new ways to determine environmental stresses and new techniques for transforming existing data.

Researchers also began to study various methods of estimating heat exchanges and developed risk scenarios for climatic conditions that could jeopardize the performance of equipment when those conditions were present in certain combinations.

But as in other cases, GSL's abiding first objective was to determine what was likely; for as Krause observed, there had been "a lot of disagreement on extreme conditions" and the frequency of occurrence of such conditions [Interview with Paul Krause, Fort Belvoir, Va., 24 October 1984.[20]] The evolving BEES, and GSL environmental work as a whole, can be seen as an attempt to resolve that disagreement.

BEES: Less time collecting, more time evaluating

Military planners wanted to give the commander an edge by making the battlefield environment work for him. In order to do this, the environmental data had to be accessible and understandable. Only then would the commander be able to evaluate the data, instead of spending long hours assembling it.

The BEES initiative began with a plan to use computers to tie together data automatically from "100 benchmark meteorological stations" intended to be representative of all the Earth's climate. The resulting data would be automated in easy-access form. But as work began, there was a problem with securing data for the stations where GSL scientists preferred to have them.

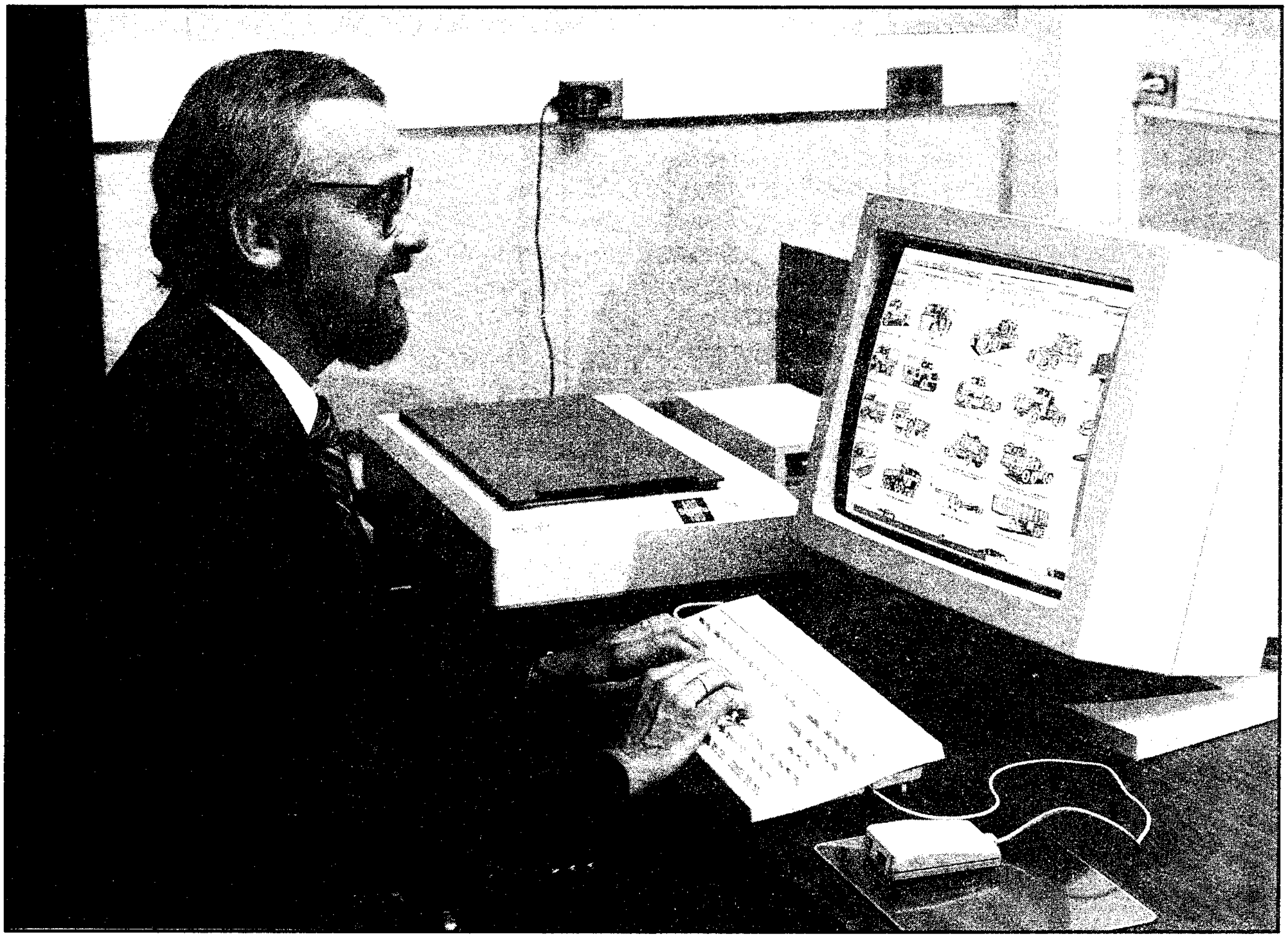
Thus, as BEES evolved in the 1984-1988 period, it had to be refocused on using a data base built on extrapolation from data on existing climatologies. The laboratory researchers first worked to get a handle on the relationship of climate to terrain in a specific, well-studied place, and then they attempted to spread it to as many parallel situations as possible.

The software, in turn, was to be designed for use on TAWS and the eventual DTSS. The goal was to provide environmental characterization and effects information to support military planning. Ideally, BEES program specialists would put together packaged information that would help the commanders in the field predict the conditions they were likely to face and how these conditions would affect equipment, personnel and operations.

Environmental data for designers

Laboratory scientists continually expanded and refined the environmental data base in the 1984-1988 period, but several researchers anticipated derivative applications of the environmental data that had been collected — uses fully as important as BEES software refinement.

In 1984, Environmental Effects Branch (EEB) researchers asked: "why not computerize what is done through telephone conversations with designers, developers and the writers of military specifications?" [Interview with Paul Krause, Fort Belvoir, Va., 24 October 1984.[21]] In other words, why not make the growing USAETL environmental data base accessible to specification writers and designers? Plans were immediately made to do just that.



USAETL researchers were working to "improve the method of assessing the environmental impact on materiel during the development and testing phases."

Avoiding both over and under design

GSL's researchers outlined the problem this way:

"In many instances, the impact of the environment is not being properly addressed during the development and test phases. Numerous examples of both over design and under design exist." [*Tech-Tran*, Vol. 14, No. 1, Winter 1989, page 4.[22]] USAETL scientists were doing something about both of these problems. Obviously, there were manifold causes for cost overruns, and over design was just one of them — but USAETL could correct this.

In-house specialists turned their attention to instances where such "gold plating" resulted from a lack of understanding of environmental factors and "not enough flexibility in existing stringent design criteria." [Ibid.[23]]

"Over designs" cited

GSL researchers were able to cite numerous cases where equipment was designed to operate at 160 degrees Fahrenheit and 95 percent humidity. There was some amazement on the part of GSL scientists when USAETL's arduously collected data bases proved there had never been a record of ambient air temperature close to 160 degrees on Earth (the highest recorded being 136.4 in Libya), nor was such a temperature likely to be accompanied with 95 percent humidity. One researcher observed humorously that one of these absurd systems was designed to be used only at night!

Costly retrofitting

Nor was such over design the only problem. EEB researchers also cited many cases of under-designed equipment already being fielded that could not work without expensive retrofitting for its new environment. A helicopter to be used in Germany, for example, iced up and could not be used until design modifications were hurriedly made. The reason was that its testing had been undertaken in a cold but dry climate, while Germany, though cold, is often wet.

GSL scientists observed that the process could have been less expensive, or even unnecessary, if possible

environmental effects had been factored in earlier in the acquisition cycle. More than that, the Army could avoid making potentially disastrous repairs in the field.

Lesson of events

Researchers were unlikely to soon forget the equipment failure in the desert when President Carter directed an attempt to rescue the hostages in Iran. Research did not take place in a vacuum. And here, as elsewhere during this period, laboratory scientists continually profited from their exposure to the field-experienced colleagues in the Terrain Analysis Center. They learned that equipment had to be designed to meet real conditions.

GSL researchers were equally attuned to field experiences of over design cases. It also was part of the program to see where corners could have been cut and money saved without doing any harm to the efficacy of the final product.

Avoiding worst case

Though troublesome, some over design and under design problems could be addressed with minor corrections to the system. But, as occurred in some cases, when both errors in design had taken place, simple solutions were unlikely.

The answer was to "improve the method of assessing the environmental impact on materiel during the development and testing phases." [Ibid[24].] That answer was to come from the Environmental Design Guidance for Evaluation (EDGE) research and development program, conceived at the start of the 1984-1988 period.

EDGE: An automated environmental design system

By this time, the Army acquisition community was eager to consult such directives as Army Regulation 70-38, *Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions*,[25] and USAETL was among those working toward revisions of that document to meet the more "rational standards" cited above. But no matter how up-to-date the information might be, there remained the problem of access. Getting the right information too often required a "slow, time-consuming search." [*1991 Organizational Activities*, GSL, page 2.[26]]

Needless to say, the years GSL's researchers had spent in the USAETL community had impressed upon them the virtues of automated data systems. Accordingly, it was decided to put together such a system for environmental design: the computer-based EDGE system.

Many sources into one

Through the 1984-1988 period, the outlines of EDGE came into sharper focus. A plan was drawn up to incorporate interactive computer programs filled with the type of information still tucked away in Army regulations, military standards, environmental guidelines and test methods, test and field reports, and environmental data bases. The advantages over such hard-copy sources in bulk alone were significant; the pluses in push-button convenience were even more obvious.

Acquisition process, start to finish

GSL's specialists saw EDGE as providing "quick, easy, and accurate access to the information," and automating the documentation required "throughout the acquisition process" from concept through development to fielding and evaluation. [Ibid.[27]] EDGE was to centralize and computerize the maze of environmental regulations, information, constraints and lessons learned.

The scientists involved in developing EDGE wanted to ensure that realistic design criteria were established, not on paper, but in fact. Only in this way could adequate testing and evaluation be guaranteed, and profitable experience be easily "fed back" into the system. [Ibid.[28]] Thus, the tailoring process would be well documented, and the requirement documents and reports could be standardized.

Savings in two areas

The obvious savings expected through EDGE were twofold. First, the designer's work load would be greatly reduced by easing the preparation of requirement operation capabilities and reports. The designer would now use the expert systems automation approach and have ready access to the needed data from one user-friendly computer-based system.

Second, and perhaps foremost, the designers would have their environmental parameters factored-in early in the developmental process. Thus, USAETL scientists hoped to make environmental over design and under design a rarity in the 1990s.

In the final analysis, GSL's work into using environmental factors to an advantage provided an edge to the commander, in both the information and the equipment he was provided.

4. RESEARCH INTO EXPLOITING IMAGERY AND VISUALIZING THE TERRAIN

When asked to recount the major trends at the laboratories in the 1984-1988 period, two of USAETL's scientists cited the trend away from hard-copy maps toward soft-copy terrain "visualization." [Interviews with Anne Werkeiser, Fort Belvoir, Va., 16 May 1991;[29] Richard Marth, Fort Belvoir, Va., 17 May 1991.[30]]

What was urgently needed was a better way of depicting terrain information. USAETL had succeeded somewhat in speeding up, but certainly not in automating, the process of turning the information in aerial photos and remote sensing imagery into maps. While long-term research into making such automation a reality proceeded, USAETL turned to exploring ways to make existing information more understandable to the commander in the field.

As work on streamlining the mapmaking process continued, GSL scientists focused on what the commander really needed, what he could readily understand, and what he could really be provided. [*Army Environmental Sciences*, Vol. 8, No. 2, Fall 1989, page 3.[31]]

"Digital Topographic Revolution"

Most of the better ways of visualizing the terrain were emerging as a result of the "Digital Topographic Revolution." Though producing a "map" by converting aerial imagery into DTD was proving no faster than traditional mapmaking and cartography, USAETL researchers had foreseen some intriguing possibilities once the end product was in the form of DTD. Work on terrain analysis products, such as those that might be provided by DTSS, were a primary focus of TDL.

At the same time, GSL explored ways to turn aerial imagery itself into an intelligible source of terrain information, taking advantage of the fact that such imagery was both widely available and more up-to-date than the admittedly more informative terrain analysis products pursued by TDL.

The task could be seen in terms of pursuing the ideal terrain information from opposite ends. One approach favored the highly informative terrain information product, while urgently pursuing ways to make this product *more up-to-date*. The GSL approach, in turn, took already up-to-date imagery (e.g., from Landsat or SPOT imagery) and standard DMA DTED and sought to make it *more informative*, through new visualization techniques.

The latter approach was not an entirely new avenue of research at GSL. Indeed, even the exploratory work during this period on GSL's Terrain Visualization Test Bed finds its origins in much earlier work.

Work on Computer Image Generation for DARPA

USAETL's first initiative toward terrain visualization took place back in the early 1980s, when the Defense Advanced Research Projects Agency (DARPA) awarded an early concept development contract to Boeing Aerospace to develop a technique for determining how much of an object in a computer scene is visible from a particular viewpoint.

The resulting "depth buffer" algorithms were so promising that DARPA joined USAETL in a second phase of the contract to implement the depth buffer algorithms into a software system as a "proof of concept." That work was completed in the first year of the 1984-1988 time frame.

Three scene-generation systems developed: 1984-1988

In late 1984, the successful Computer Image Generation (CIG) work moved DARPA to award a development contract to Boeing to develop three visual scene-generation systems. The first system, co-sponsored by USAETL and the U.S. Army Missile Command (MICOM), was a software system to generate images strictly in a software environment. When delivered in September 1987, the system could generate images in 3 to 15 minutes.

The other two systems focused on producing real-time visual images, with one being readied for MICOM and the other for USAETL at the close of 1988. While the aim was much the same as the software system finished in 1987, the latter two systems used hardware and generated images at up to 30 frames per second.

Toward visual realism

Generating images at 30 frames per second enabled operators to use joysticks to simulate flying or driving through the realistic data base "exactly as if in an aircraft or a tank." [*Army Environmental Sciences*, Vol. 8, No. 2, Fall 1989, page 5.[32]] With images popping up in a 30th of a second, the scene was beginning to resemble the flickering but highly intelligible "kinescope" motion pictures of old, although now in color, and based on digital data. The key was using

polygons, breaking the surface into triangles "which processed efficiently," thereby allowing rapid generation. [Interview with Laslo Greczy, Fort Belvoir, Va., 16 January 1992.[33]]

The implications of this technology were many. The most obvious plus would be the ability of a commander to simulate a "drive" or "flight" through the prospective battle scene:

"Before his unit even crosses into enemy territory, he will know what the terrain looks like, where buildings and industrial facilities are located, and what obstacles to avoid." [*Digital Data Digest*, Vol. 1, No. 2, Fall 1990, page 7.[34]]

More than that, the commander would be looking at something that closely mimics what he would later see in fact. In addition, well before the battle, he would be able to play out various scenarios to better anticipate the results of his plan. The objective was to "provide military commanders with readily understandable representations of complex battlefield situations, allowing for better planning and execution of tactical operations." [Ibid.[35]] And, at long last, the quality of the decisions he made would be based on his tactical acumen rather than his ability to rapidly interpret a busy map.

Designing a TVTB

But in order to make this visual realism an operational reality, scientists had to work out a number of problems. First among them was establishing the data base requirements that supported visual realism.

In order to work out this and other problems, the Army needed a laboratory-based terrain visualization capability. This capability evolved into USAETL's Terrain Visualization Test Bed (TVTB), which was placed within the Terrain Visualization Division of GSL.

Tailored to other systems

The ability to rapidly portray and effectively visualize battlefield information had so much potential value that, from the start, the TVTB was not envisioned as a stand-alone system. Rather, it was seen as something that could be incorporated into other Army programs such as ASAS, the Maneuver Control System (MCS), and USAETL's own DTSS. Those systems, in turn, were being favorably reassessed by a "whole assortment of users," including "air defense and maneuver elements," by the end of 1988. [Interview with Laslo Greczy, Fort Belvoir, Va., 16 January 1992.[36]]

How TVTB worked

Unlike DTSS and other emerging systems dependent on DTD from DMA, the visualization test bed started with imagery from Landsat or SPOT satellites received in digital form. Using equally available Digital Terrain Elevation Data (DTED) from DMA, the digital imagery was then made to correspond to the elevation truths and thus, "brought down to earth." Then, to lend a note of added realism to what a nonprofessional might see as "martian landscape," further experiments late in the 1984-1988 period made use of artificial digital features such as buildings, trees and even tanks.

The direction of research was toward greater realism. The aim was to give the commander a picture of what he would actually see if he were to undertake a given operation in a given place. Such an approximate visual picture, when tied in with the highly informative and accurate terrain analysis products possible with DTSS, for example, would provide the edge in battle.

ALBE: Securing an edge from terrain and weather

In the past, commanders had very limited available knowledge of environmental factors when planning a battle. This remained true even though it was widely accepted doctrine that "terrain and weather affect combat more significantly than any other physical factors." With the very real possibility of U.S. forces being outnumbered in conflicts in a variety of theaters, making such environmental factors work in the Army's favor would be what the Army liked to call a significant "force multiplier."

But it was one thing to recognize the value of environmental information and quite another to get it in hand. The problem was that traditional manual methods of furnishing environmental information to the field commander were far too slow to be of much use in continuous operations. The problem was particularly acute when viewed in the context of a larger force that could be expected to move rapidly in adverse weather, take full advantage of terrain, use smoke during movements, and employ weapons that have a range and capacity for damage far exceeding anything seen in the past.

Doctrine of AirLand Battle

In order to counter this threat, the Army had embraced the "AirLand Battle Doctrine," the Army 21 Concept, and the Focus 21 Concept. These initiatives meant that the Army was determined to field a combat force that could move quickly to strike a disabling blow to the enemy. This, in turn, presumed not only a knowledge of the enemy but also the availability of up-to-date terrain and weather information, and the likely effects of both on operations.

And, indeed, "presumed" was the right word. To this point, commanders had not been provided the environmental information required, at least not in what one could call a timely or up-to-date form. Something

new had to be done to provide tactical support for AirLand Battle as the doctrine envisioned it.

ALBE thrust

The battlefield environment in ALBE was envisioned as including five elements:

1). Atmosphere (meteorology, climatology, atmospheric physics and aerosols/composition).

2). Terrain (topography, soil, vegetation, hydrology, cultural features, snow and ice, surface and subsurface composition and conditions).

3). Battlefield-induced contaminants (BIC) (induced weather, dust, smoke, fire products, and nuclear, biological, chemical and other battlefield contaminants).

4). Background signatures (electromagnetics, acoustic, seismic, biological and chemical).

5). Illumination (natural and man-made)

The ALBE thrust was to make use of all these factors. Indeed, these elements were meant to cover all interactive and synergistic aspects of air, land, water, BIC, illumination and background signatures that influence tactical weapons in combat operations. To turn the battlefield environment into an edge, information was needed on the terrain and the environment.

Terrain and weather specialists to the rescue

At USAETL, with its long history of working to streamline mapmaking, scientists understood this shortcoming better than anyone. Certainly no one needed to explain the value of current terrain and weather information to the scientists at TDL and GSL, or the busy specialists at the Terrain Analysis Center. Nor did anyone need to explain to them the difficulties inherent in providing such information quickly, in an up-to-date form.

USAETL was an obvious choice to participate in the Corps of Engineers' ALBE Demonstration and Evaluation program, an effort to coordinate Army technology base efforts in the environmental sciences. In this effort, USAETL joined the U.S. Army Construction Engineering Research Laboratory, U.S. Army Cold Regions Research and Engineering Laboratory, U.S. Army Engineer Waterways Experiment Station, along with the U.S. Army Materiel Command's U.S. Army Atmospheric Sciences Laboratory. The U.S. Army Intelligence Center and School at Fort Huachuca, Ariz., was selected as the U.S. Army Training and Doctrine Command's proponent for ALBE .

Stages in implementing ALBE

The common labor of the Corps' laboratories was to assure that the ALBE program would be properly supported. To that end, ALBE was envisioned in several stages, including assembling an ALBE test bed, installing TDA software, conducting field demonstrations and evaluations, and eventually transferring the software to several target systems that were scheduled for fielding in the near future.

The first step, assembling a test bed, drew heavily upon USAETL's experience with its TAWS, a tech base version of the ALBE test bed that had been created at the start of the 1984-1988 period.

Background from TAWS

In spring of 1983, USAETL's experience in civil works projects investigating the Analytical Photogrammetric Positioning System (APPS) was used to jump start the TAWS projects in GSL's Terrain Analysis Group. Walter Boge, then-GSL director, and the first TAWS project engineer, Greczy, set to work building a station that could create and update digital data bases in the field. Such a station would extract digital data from a variety of hard-copy sources and revise or intensify already existing digital data.

Too often in the past, the field commander had been, in Orsinger's words, "deluged with information" rather than provided with what he needs. [Interview with Regis Orsinger, Fort Belvoir, Va., 1 July 1991.[37]] Specifically, the commander required information that was up-to-date and in usable form. In hopes of filling this demand, Army planners turned to DTD for the eventual answer.

But Army researchers recognized that such data, provided typically by DMA, often could not meet the commander's needs. There were abiding problems with accuracy, resolution and operational format. Furthermore, DMA data might well be out-of-date by months or even years. Then, there was the problem of making a tactical decision based on either outdated data of this type, or perhaps hard-to-interpret hard-copy data that was outdated as well.

Closing data gap

USAETL's specialists knew that DMA's crushing work load precluded counting on the availability of the required data in a timely manner. Since U.S. military commitments spanned the globe, it was wholly unrealistic to expect DMA to provide the Army with all

the digital terrain information it wanted for every area of strategic or tactical interest. And, in addition to this almost certain shortfall, USAETL's 1984 and 1987 Digital Topographic Data Requirements Studies would emphasize how many Army systems were evolving that intended to make use of DTD. On a number of fronts, the gap was growing between what was needed and what could actually be provided. DTD studies (discussed at length elsewhere) revealed a host of problems, but first among them was the fact that many future Army systems were being designed under the assumption that a digital data base existed, or would soon exist, to support them. As this was often not the case, the effort to create a system to provide custom data bases became a "high-priority USAETL project." [*Tech-Tran*, Vol. 8, No. 4, Fall 1983, page 3.[38]]

Providing tactical information

USAETL researchers drew upon experience with civil works projects investigating the APPS. Project engineer Greczy began to put together TAWS. The immediate goal was to demonstrate how the system could extract digital data from a variety of hard-copy sources and revise or intensify already existing digital data. In other words, TAWS would show how to provide the tactical information needed by the field commander. Accordingly, USAETL scientists and engineers created the system to explore the possibilities of compiling digital data in the field and turning them into customized products tailored exactly to the commander's needs. To that end, researchers made full use of three existing USAETL systems: CAPIR, DTAS and BEES. From the beginning, TAWS software was designed in modular form to permit easy updating and to allow it to be adapted to other systems without costly modifications. It also was designed to be portable and easily exchangeable with other systems; and to be device-independent so that peripherals could be added without rewriting the software. And, as always, USAETL engineers kept the soldier in mind by striving to make TAWS user friendly. This was done by getting terrain team input during a series of planned demonstrations. The first major "TAWS show" took place in October 1985.

Toward union with DTSS

Just as the DTAS built the technology base for DTSS in the years 1979-1983, TAWS in this later period, worked toward eventually giving DTSS the ability to create and update digital data bases. More than that, however, the work station must be seen historically as defining and developing requirements for DTSS and introducing digital map technology to the field prior to DTSS deployment.

Demonstrating TAWS in 1986

The year 1986 saw three successful field demonstrations at military installations in North Carolina, Hawaii and Washington state. After training, the Corps' terrain team in North Carolina used TAWS to produce over 150 terrain products in a 1-week period. For the Fort Lewis, Wash., session, a TAWS was mounted in a mobile van for the first time. [USAETL Annual Historical Summary for Calendar Year 1986, unpaginated.[39]] The mounted system included a Hewlett-Packard computer, disk and tape drives, line printer, plotter, digitizer, five interactive terminals, and the Light Mensuration System (LMS). The LMS would later be replaced by a much more effective component.

TAWS "Superset": ALBE

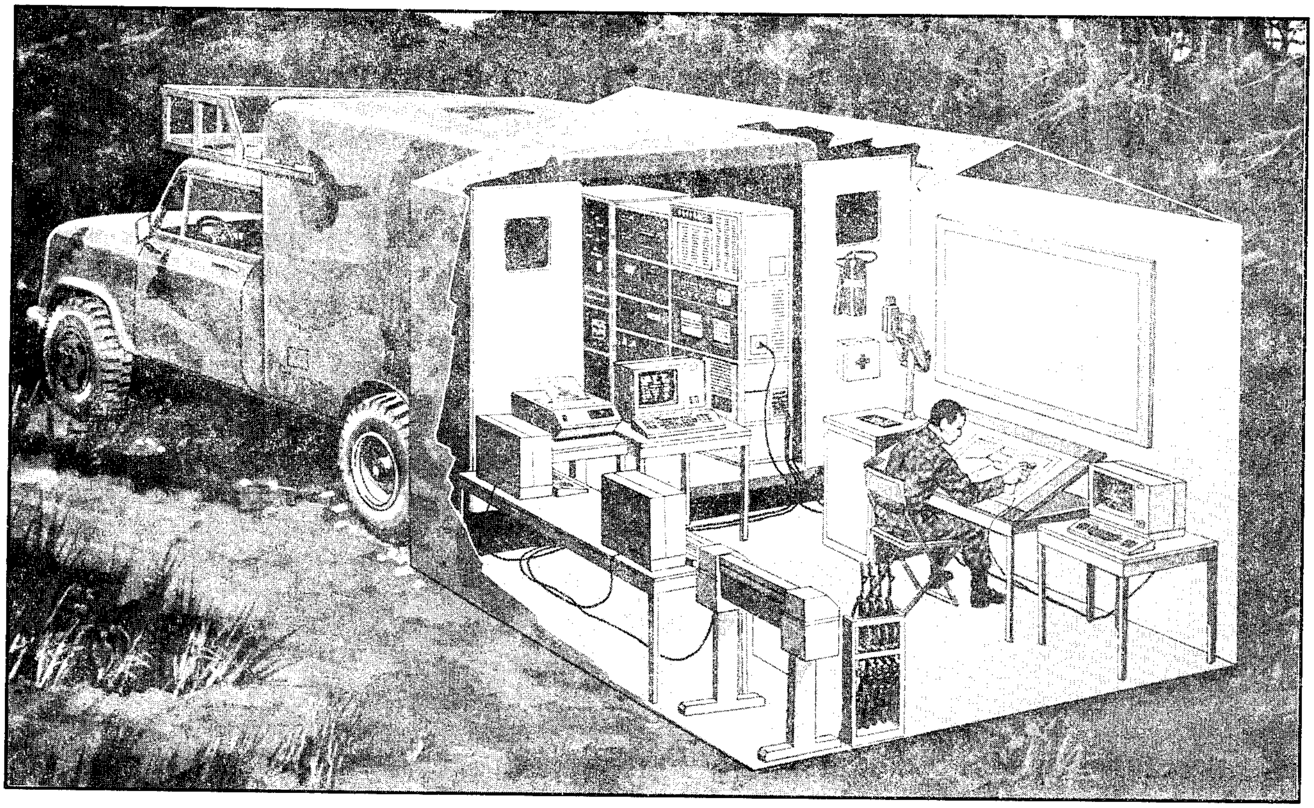
The TAWS demonstration at Fort Lewis was a part of the continuing ALBE Test Bed Demonstration program. That program, again, was initiated to allow the Army to secure a tactical edge through correctly assessing and making use of battlefield environmental effects. To that end, the system was to develop and evaluate TDA software and products that might enable the terrain teams to get terrain and environmental factors worked into the battlefield prediction equation. The ALBE test bed was not designed to be fielded, but selected software and hardware capabilities were to be transferred to fielded systems that were existing at the time or anticipated in the future. It was, in essence, a "superset TAWS." [Interview with Laslo Greczy, Fort Belvoir, Va., 16 January 1992.[40]]

TDAs for AirLand Battle

The aim was to develop the capability to measure and monitor the environment in real time by means of state-of-the-art automated and distributive sensors. The resulting intelligence was to be put in the ready form of TDAs and passed on quickly to field commanders and their staffs.

The TDAs consisted of computer software that produced products that showed commanders the significant effects environmental factors were likely to have on equipment, weapon systems or operations. George Aitken, of the Corps' Directorate of Research and Development, stressed that the TDAs were envisioned as a help, not an answer:

"The TDAs are not intended to make decisions by themselves, but rather to supplement the tactician's knowledge base and help guide him during the decision-making process by providing information useful in the formulation and execution of battle strategies." [George W. Aitken, *AirLand Battlefield Environment Overview*,



AirLand Battlefield Environment (ALBE) Test Bed

Installation Files, unpaginated.[41]]

Though they themselves made no decisions, the TDAs made decision-making easier. In so doing, they provided, in Greczy's words, "an invaluable aid in the formulation and the execution of both pre-battle and near-real-time tactical decisions." [Laslo Greczy, *AirLand Battlefield Environment (ALBE) Demonstration*, Installation Files, unpaginated.[42]]

The benefits of such informed decision-making were expected to be felt in three major areas: target and situation development; mobility/countermobility; and prediction of hazards from nuclear, biological and chemical weapons.

Six TDA categories developed

Researcher Greczy cited six categories of TDAs, each designed to enhance the commander's ability to plan and execute operations "in a dynamic tactical situation, and let commanders and their staffs use weather and terrain as force multipliers." [Ibid.[43]] GSL's Betty Mandel, who worked on ALBE from 1986 to the end of the period under consideration, described the focus of each category as follows:

Army Aviation: TDAs demonstrating the application of terrain and atmospheric models in the analysis of aircraft performance, producing screen graphic plots and textual reports.

Countermobility: TDAs evaluating the effectiveness of obstacle deployment considering the state of the environment, troops and equipment, and time constraints.

Ground Mobility: TDAs providing a comprehensive description of vehicle capabilities on and off road.

Nuclear, Biological and Chemical (NBC): TDAs giving information on the location, extent, and persistence of NBC hazards and smoke; the benefits of using protective clothing; and the options for decontamination.

Weapon Systems Performance: TDAs consider the environmental effects on the effectiveness of electro-optical, seismic and acoustic sensor systems.

Terrain and Atmospheric Utilities: TDAs providing general supporting utilities which were used as input by others or as stand-alone products. [Betty Mandel, *ALBE Provides Tactical Advantage*, Installation Files, unpaginated.[44]]

All these TDA products were meant to be implemented by Army systems "as soon as possible." [Ibid.[45]] Whatever capabilities were developed and demonstrated under the TDA program were transferred to developmental systems such as DTSS, ASAS, MCS

and Integrated Meteorological System.

By the end of 1988, TDAs existed on road speed (5), off-road speed (11), gap crossing (92), other ground mobility (3), minefield deployment (97), obstacle deployment (8), intervisibility (11), surface and upper air data (16), electro-optical systems performance (2), and aviation (2).

ALBE economies

The ALBE test bed was a tech base demonstration system designed to demonstrate and evaluate software prior to incorporating it into developing Army systems. It was done in this fashion in the interest of economy, both in time and cost. It was thought that ALBE products would have been both significantly delayed and more costly if they had gone through the normal life-cycle process. This "end run" had a further advantage over ongoing life-cycle developments because it could make full use of new capabilities being developed in the Army laboratories. [George W. Aitken, *AirLand Battlefield Environment Overview*, page 15.[46]]

The ALBE program sought to give the battlefield commander the earliest possible access to the environmental effects information that GSL scientists knew to be vital in the decision-making process.

TAWS was a lab version of what an advanced development system would look like. Both ALBE and TAWS were proof of concept and "breadboarding" (i.e., showcasing) of DTSS. Yet, the two showed capabilities far beyond what had been planned. [Interview with Laslo Greczy, Fort Belvoir, Va., 16 January 1992.[47]]

Greczy foresaw an expanded role for this technology as it became "apparent that more folks needed these products than terrain analysts." A "broader view of the end user" emerged for TAWS and ALBE that would become even clearer with the development of DTSS. [Ibid.[48]]

5. "SON OF CAPIR": THE TERRAIN INFORMATION EXTRACTION SYSTEM

Against a background of improving computer technology and shrinking computing costs, many Army planning and control functions continued to be automated in the years 1984-1988. It was obvious that doing so implied not only getting terrain data in digital form, but getting it with sufficient detail and resolution. The Defense Mapping Agency (DMA) had begun its massive program to go all-digital for the 1990s but the question remained: would the right Digital Topographic Data (DTD) be there when the emerging Army systems required it?

During these years, DMA was producing Digital Terrain Elevation Data (DTED) and Digital Feature Analysis Data and largely had its hands full doing that. Yet, at the same time, USAETL's Digital Terrain Data Requirements Study (1984) had sounded a warning that many emerging systems would need different, usually much more detailed data sets.

Challenge and an opportunity

So it was that during these years USAETL's scientists came to see the shift to digital terrain data as not only an opportunity, but as a formidable challenge. The opportunity was to make judicious use of the digital data available from DMA. Specialists saw the possibility to provide much better field support, and to that end, they worked to exploit the speed of the computer, as well as the enormous flexibility of digitally stored data. Such data could more easily be brought up-to-date, and had the added plus of lending itself to techniques that enabled field commanders to better visualize the terrain, and thereby more quickly assess its effect on operations.

The challenging side, however, related back to the now-familiar mapmaking bottleneck. Due to the laborious nature of making maps (whether digital or hard-copy), the Army could not simply assume that there would be ideal DTD support. Indeed, it often had to deal with the need to create the necessary terrain data when none existed.

Help slow in coming

The shortage of data was acutely felt during these years. Indeed, it was widely recognized within USAETL that, for all its promise in other respects, the massive modernization of DMA would not eliminate a number of manual functions from the process of extracting terrain data from imagery. Moreover, the very manual functions not lending themselves to automation were invariably time-consuming, labor-intensive, and prone to error. In short, help was not just around the corner.

Well before the 1984-1988 period, during the days of computerized statistical pattern recognition, the optimistic scientists had experienced a rude awakening. They came to see that automating the imagery-to-map process was going to be a complicated and long-term exercise at best. More things could be done with DTD once it was in hand, but producing it was to remain a considerable chore for the foreseeable future.

Toward an Army Data Generation Facility

Finding a way to fill the gap between Army needs and DMA's ability to provide support was a major aim of USAETL research in these years. GSL scientists looked hard at using imagery and then-current technology for help. Fortunately, much of that help was derived from a CAPIR system that had its origins within USAETL itself. To understand the push for an Army data generation facility, one needs to review the importance of that initiative of a few years earlier.

Background to CAPIR

Through the years 1979-1983, George Lukes in the Research Institute worked on ways to help the specialist who was saddled with the unenviable tedium of extracting terrain information from stereoscopic aerial photography. The results of his extensive investigation of available hardware and software was a system linking the Fish & Wildlife Service's Wetlands Analytical Mapping System (WAMS) with a high-precision measuring instrument called the APPS-IV analytical plotter.

Following the invention of stereo "super-positioning" by Lukes and Dr. Robert Leighty in 1982, the package really came together as CAPIR. The CAPIR operator could now "float" the emerging feature map into the stereo view, and thereby compare at a glance what was going into the data files with the line suggested by the photo. The editing or verifying of existing files now merely required comparing the stored information with up-to-date stereo photographs.

USAETL researchers set to work immediately showcasing the merits of CAPIR, both as it was, and as it might become with enhancements. Greczy gave civil works demonstrations of CAPIR uses for dam monitoring, as well as analysis of urban areas. After using CAPIR to fashion a 3-D data base of Fort Belvoir from NASA photos, Daniel Edwards turned directly to enhancing the system by making use of Artificial Intelligence (AI). To that end, Edwards underwent AI training from 1985 to 1986.

In 1985, USAETL's TAWS incorporated CAPIR capabilities in a field Army demonstration system. The Army Space Program Office, the Air Force and the Joint Cruise Missile Program Office identified CAPIR components for use in new geographic information and intelligence systems. The Central Intelligence Agency installed CAPIR hardware and software as part of a new national image exploitation test bed. There were other CAPIR users as well, including DMA and the Corps of Engineers' civil works programs.

Crash in Gander, Newfoundland: 1985

World events played a role in spurring further work in response to a demonstrated need, and in showcasing the value of research already completed. Following a major aircraft accident in Gander, Newfoundland, in December 1985, Gen. Maxwell Thurman asked that USAETL provide assistance to the Armed Forces Institute of Pathology and the Canadian Aviation Safety Board. CAPIR was used to provide precise measurements of trees that had been severed during the crash, enabling the investigators to determine the plane's orientation before crashing and thus, perhaps help find the cause of the crash. In so doing, CAPIR "helped validate high-resolution mapping from imagery." [Interview with Daniel Edwards, Fort Belvoir, Va., 2 July 1991.[49]]

Turning concept into a better system

CAPIR had begun its life dealing with "standard frame photos" which it used to generate digital terrain data, but it was apparent to USAETL scientists that future inputs would include imagery of another sort. In these years there had been a revolution in the diversity and performance of remote sensing acquisition systems based on electronic sensors recording image data digitally. Clearly, it would take something like CAPIR, but more advanced, to put all this incoming data into usable form.

CAPIR had, however, served to prove a concept. Elsewhere at USAETL, Dr. Leighty employed CAPIR to help provide very detailed data for the Defense Advanced Research Projects Agency's (DARPA) Autonomous Land Vehicle. Though CAPIR remained essentially a prototype system, Edwards cited its importance in "proving the value of high-quality image mapping from imagery." [Ibid.[50]]

Building on CAPIR at USAETL

Edwards, who spent many years in this area of research, observed later that the CAPIR idea had spread throughout the mapping community, although some of its specific equipment had not. The reason for this is to be found in USAETL's relentless search for better and cheaper ways to do things. During 1984-1988, CAPIR would be gradually enhanced and improved until overtaken by a better, cheaper and more encompassing system called the Terrain Information Extraction System (TIES).

The key step toward the eventual TIES, however, would be the development of a soft-copy work station, the Digital Stereo Photogrammetric Work Station

(DSPW). Though TIES would be seen as "Son of CAPIR" in many eyes, it also was meant to be an "umbrella concept" that included devices, such as the DSPW and Image Digitizing System, that could do much more. [Interview with Douglas Caldwell, Fort Belvoir, Va., 22 May 1991.[51]] Paul Logan, Maurits Roos and Edwards worked throughout these years to turn this concept into a reality.

ERDAS: Imagery processing capability for DTSS

A Softcopy Exploitation work unit at GSL supplemented these efforts by looking for ways to bring an image processing capability to DTSS. The initial goal was to provide DTSS, which was fueled by DTD from DMA, with the capability to do a "limited update of its data bases." [Interview with Paul Logan, Fort Belvoir, Va., 5 February 1992.[52]] The currency, as well as the availability of DMA's DTD, was always a concern to GSL researchers.

Might not DTSS, with hardware modifications, be able to incorporate something to update its data base? To answer that question, GSL's John Anderson obtained a commercial Earth Resources Data Analysis System (ERDAS) image processing system in 1988 and worked with Steve Hasenfus and Logan on "investigating ERDAS for possible use in DTSS." [Ibid.[53]] The researchers used satellite imagery from Landsat and SPOT (multispectral imagery) which was readily available and looked for ways to turn its spectral classifications into genuine information classifications. [Interview with Gregory Desmond, Fort Belvoir, Va., 5 February 1992.[54]] The ERDAS team was convinced this or some other image processing system would have an application in DTSS or GSL's own TIES system. [Interview with Paul Logan, Fort Belvoir, Va., 5 February 1992.[55]]

Consolidating feature extraction work: TIES

Viewed against the background of USAETL's expanding role in managing Army digital terrain data demands, and the laboratories' focus on turning such data into the optimal terrain visualization for the field commander, GSL's TIES initiative can be seen as complementing that work. TIES was to be a computer-assisted technique for extracting, editing, enhancing and storing DTD from hard-copy and soft-copy mapping and reconnaissance imagery.

This collection of integrated systems was yet another source for the eventual data base that would support the systems of the future, yet it also could be seen as providing an alternative source of terrain information to the commander for cases where DMA's DTD was either nonexistent or ill-suited. The TIES product was extracted directly from imagery making it more up-to-date. A system like TIES had strong possibilities in the hands of commanders with a knowledge of reading and understanding imagery maps.

As a versatile, comprehensive system, its development stood to result in closer cooperation and technology transfer with various Department of Defense agencies. [*Tech-Tran*, Vol. 17, No. 1, March 1992, page 5.[56]] Technology also had been transferred to other government agencies, e.g., the U.S. Geological Survey and the Central Intelligence Agency, which obtained copies of key TIES components to investigate for applications to their own missions. Furthermore, companies involved in development of TIES components continued to enhance them for the commercial market.

Footnotes

1. Keith Kurtz, Memorandum to TDL Director, Fort Belvoir, Va., 19 May 1992.

2. Ibid.

3. DTSS Historical Facts, In-house Document, Installation Files, 17 October 1990, p. 2.

4. Interview, author with Regis Orsinger, Fort Belvoir, Va., 1 July 1991.

5. Interview, author with Frank Capece, Fort Belvoir, Va., 14 October 1984.

6. Interview, author with Douglas Caldwell, Fort Belvoir, Va., 22 May 1991.

7. USAETL in-house QRMP document, unpaginated.

8. Ibid.

Footnotes, continued

9. *FY84 Laboratory of the Year Report*, p. i.

10. *FY85 U.S. Army Laboratory of the Year Report*, p. 15.

11. *FY84 Laboratory of the Year Report*, p. 6.

12. USAETL in-house QRMP document, unpaginated.

13. Interview, author with Dr. Kenneth Kothe, Fort Belvoir, Va., 11 October 1984.

14. *Army Research and Development Organization of the Year Report for FY88*, p. 11.

15. Interview, author with Paul Krause, Fort Belvoir, Va., 5 February 1985.

16. Interview, author with Paul Krause, Fort Belvoir, Va., 5 February 1985.

17. *Army Research and Development Organization of the Year Report for FY88*, p. 11.

18. *1991 Organizational Activities*, GSL, p. 1.

19. Ibid.

20. Interview, author with Paul Krause, Fort Belvoir, Va., 24 October 1984.

21. Interview, author with Paul Krause, Fort Belvoir, Va., 24 October 1984.

22. *Tech-Tran*, Vol. 14, No. 1, Winter 1989, p. 4.

23. Ibid.

24. Ibid

25. Army Regulation 70-38, *Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions.*

26. *1991 Organizational Activities Draft*, GSL. p. 2.

27. Ibid.

28. Ibid.

29. Interview, author with Anne Werkheiser, Fort Belvoir, Va., 16 May 1991.

30. Interview, author with Richard Marth, Fort Belvoir, Va., 17 May 1991.

31. *Army Environmental Sciences*, Vol. 8, No. 2, Fall 1989, p. 3.

32. *Army Environmental Sciences*, Vol. 8, No. 2, Fall 1989, p. 5.

33. Interview, author with Laslo Greczy, Fort Belvoir, Va., 16 January 1992.

34. *Digital Data Digest*, Vol. 1, No. 2, Fall 1990, p. 7.

35. Ibid.

36. Interview, author with Laslo Greczy, Fort Belvoir, Va., 16 January 1992.

37. Interview, author with Regis Orsinger, Fort Belvoir, Va., 1 July 1991.

38. *Tech-Tran*, Vol. 8, No. 4, Fall 1983, p. 3.

39. USAETL Annual Historical Summary for Calendar Year 1986, unpaginated.

40. Interview, author with Laslo Greczy, Fort Belvoir, Va., 16 January 1992.

41. George W. Aitken, *AirLand Battlefield Environment Overview*, Installation Files, unpaginated.

42. Laslo Greczy, *AirLand Battlefield Environment (ALBE) Demonstration*, Installation Files, unpaginated.

43. Ibid.

44. Betty Mandel, *ALBE Provides Tactical Advantage*, Installation Files, unpaginated.

45. Ibid.

46. George W. Aitken, *AirLand Battlefield Environment Overview*, p. 15.

47. Interview, author with Laslo Greczy, Fort Belvoir, Va., 16 January 1992.

48. Ibid.

49. Interview, author with Daniel Edwards, Fort Belvoir, Va., 2 July 1991.

50. Ibid.

Footnotes, continued

51. Interview, author with Douglas Caldwell, Fort Belvoir, Va., 22 May 1991.

52. Interview, author with Paul Logan, Fort Belvoir, Va., 5 February 1992.

53. Ibid.

54. Interview, author with Gregory Desmond, Fort Belvoir, Va., 5 February 1992.

55. Interview, author with Paul Logan, Fort Belvoir, Va., 5 February 1992.

56. *Tech-Tran*, Vol. 17, No. 1, March 1992, p. 5.

Terrain Analysis Center

Meeting current and future requirements for terrain and water resources data

What is the terrain like and where do I find water? These are likely to be early questions on the lips of any commander attempting a rapid deployment. The answers, in turn, may well come from the Terrain Analysis Center (TAC) at USAETL. TAC provides a capability within the Army to meet current and future requirements for digital terrain and water resources data in support of emerging Army systems and operational requirements.

The support provided by TAC should be seen in the context of the enormous Defense Mapping Agency (DMA) modernization program, with an end date of 1992. That DMA program had been envisioned as providing traditional mapping information in standardized digital form across the board. Studies showed, however, that DMA could not realistically be expected to satisfy the Army's digital data requirements in the short-term. Nor, some argued, would DMA production meet each and every long-term need.

Terrain Analysis Center director Theodore W. Howard

USAETL's own Digital Topographic Data Requirements Study in 1984 had underlined the likely data shortfall, yet it also had pointed to a large number of emerging Army systems that would be coming on-line anyway. One of TAC's prime goals was to "fill in," producing data in the required formats, and serving as the central distribution point for transformed data and products unique to the Army. An additional TAC role was producing digital and hard-copy terrain and water resources products, and maintaining files of terrain and water resources data.

With all these emerging responsibilities, it is curious to recall that TAC was once just a small operational part of the whole picture at USAETL. In the years 1984-1988, however, TAC grew to be a truly major part of the laboratories, with more funding, personnel and space. This growth was one of the major changes in the laboratories' institutional profile in this period.

TAC's emergence also may be seen as reflecting two larger historical trends: the increasingly hands-on, "operational" role of what had formerly been largely an assembly of laboratories at USAETL; and second, the increasing acceptance of the critical importance of terrain information by the military community as a whole.

An operational mission

Commander and Director Col. David F. Maune liked to refer to one of USAETL's roles as playing "godfather to topographic units worldwide." [*Army Research and Development Organization of the Year Report for FY88*, page 1.[1]] Nowhere was this responsibility more deeply felt than at TAC, where quick-response terrain support was the rule, often in crisis situations.

Perhaps as a result of its up-front, right-now focus, TAC has a mission readily understandable to the nonprofessional. As TAC's longtime director Theodore W. Howard put it, TAC provided the Army and other Department of Defense (DOD) users with what they could use right away, often transformed from DMA terrain data. [Briefing by Theodore W. Howard, Fort Belvoir, Va., 17 January 1991.[2]] TAC sought to provide the commander with an edge by providing him with quick-response military geographic information (MGI). In simplest terms, TAC let the field commander know the terrain factors likely to influence his tactical decisions. This operational mission set TAC apart from its USAETL affiliates from the start.

Army turns to TAC

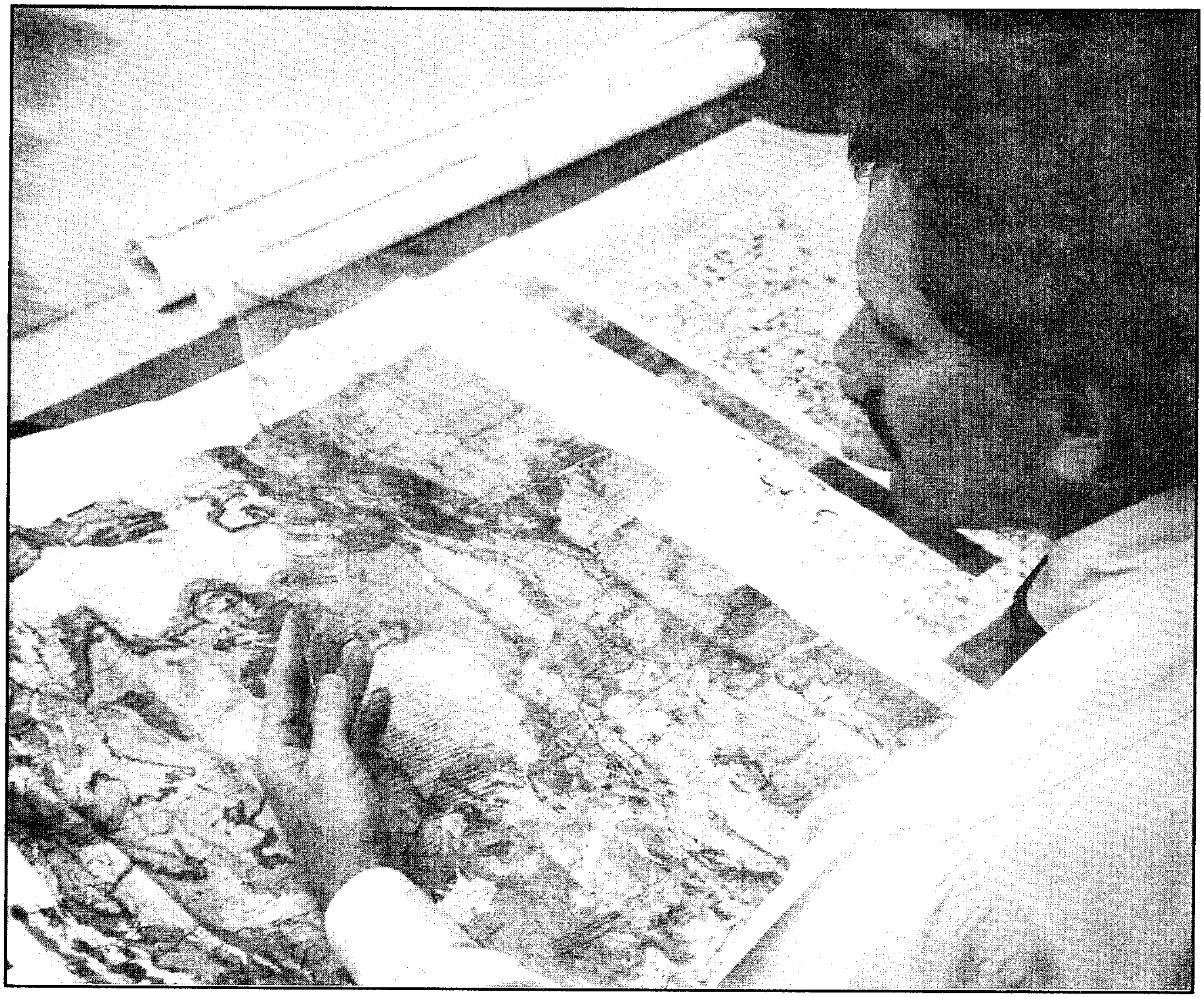
TAC grew a great deal in the years 1984-1988, as the expanded appetite for MGI inundated DMA with customer demands—especially when crises or potential crises arose. In the face of this backlog, the Army (which, in the last analysis, was funding TAC) determined that Army priorities could be best met by having TAC respond to Army needs directly, rather than letting those needs climb up the priority ladder at DMA. By 1987-1988, TAC no longer was dealing with DMA surplus requests. This was a major change from previous years.

This did not mean a diminished role for TAC at USAETL. The Army's growing appetite for terrain information (reflected throughout this history) assured quite the opposite. Howard observed proudly that TAC had tripled in size since its founding, and what had been a "small operational element" was now "a major part of the USAETL picture." [Interview with Theodore W. Howard, Fort Belvoir, Va., 24 May 1991.[3]]

Growth along old and new paths

Given the number of Army projects and products TAC undertook in these years, Howard was reluctant to single out particular initiatives but he did cite the growing work in Army Intelligence Surveys (AISs) (subsequently known as Army Country Profiles (ACPs)), and funding from the Deputy Chief of Staff for Logistics (DCSLOG) in 1987 for expanded work in water resources, along with the related establishment of the Water Detection Response Team (WDRT) in 1985. These were undoubtedly prime reasons for TAC's growth. [Ibid.[4]] In addition, funding from the U.S. Forces Command (FORSCOM) permitted the establishment of the Army Digital Data Support Facility (ADDSFAC) within the Program Support Division to

TAC analysts maintain files of terrain and water resources data.



Analysts in TAC provide support to the Department of Defense's Military Hydrology program.

provide transformed Digital Terrain Elevation Data (DTED) to MICROFIX and later TerraBase users. [Interview with Allan E. DeWall, Fort Belvoir, Va., 5 June 1992.[5]]

Indeed, TAC's expansion in these areas was so significant that by the close of the 1984-1988 period, the "laboratory" character of USAETL had taken on a strongly operational bent. So much so that one heard the first rumblings about the need for a name change for USAETL itself.

Responding to events

At this point it bears repeating that even the most abstract and intimidating research at USAETL does not take place in a vacuum. New project names do not cause changes, but rather the other way around. Research and development is initiated at the request of Army planners who, in turn, must respond to real events. Nowhere is this clearer than in the case of TAC, where the short-term, high-priority needs of the Army were met — needs that historical events often cast to the forefront.

In TAC's case, two front-page "wake-up calls," the Middle East War of 1973 and the Grenada incursion a decade later, stand out. Both were essential spurs to the rapid growth of the center which, in turn, is a major part of the USAETL story in the years 1984-1988.

Lesson one: 1973 Middle East War

Most historians agree that Israel was taken by surprise by the Middle East War, particularly on the Egyptian front where her armor took heavy losses. But, Israel was hardly alone in this, and U.S. military observers were stunned by the pace of losses on both sides.

From the carnage and dust of battle, Gen. William DePuy (then-commander of the U.S. Army Training and Doctrine Command) drew some momentous conclusions. He and others with him saw how, in that war, anything that could be seen had been destroyed in short order. Armor could "run" but too often "could not hide." From the crucial role played by terrain, and from

the fact that water had proven a vital commodity, there emerged an appreciation for the importance of terrain information in battlefield planning. Only if shielded from observation by judicious use of the terrain, could a commander really hope to bring together his full firepower for the final assault. And only if he were supplied with sufficient water could the Army commander risk such a move at all.

Background: a need for terrain information

From the lessons of the 1973 war, the now-famous "shoot and scoot" doctrine was born, but it was immediately obvious that, to employ this tactic, the commander needed to know where to shoot *from* and where to scoot *to*. Knowing all this, as well as the location of potential water, assumed not only accurate survey and point positioning, but also adequate terrain information furnished by terrain specialists. Without the information to flesh it out, mere doctrine, no matter how valid, was not enough.

There were a number of long-standing obstacles to providing this desperately needed terrain support. The remote historical cause for the absence of terrain information went all the way back to when the Army Map Service had turned its terrain analysis function over to the Defense Intelligence Agency (DIA) in the 1960s, and DIA had redirected its 600 terrain experts to other work.

As a result, there was no one left to answer the wake-up call when it finally came. There was neither a specific source nor an adequate number of expert personnel on-call to give the Army the terrain information it sorely needed.

Terrain information responsibility given to TAC

The TAC story at USAETL began in 1975, when the laboratories were still predominantly research-oriented and preoccupied with geodesy and the like. At that time, the small Engineer Agency for Resource Inventories was assigned to USAETL. This was done after a series of meetings wherein DIA and DMA determined that no one had been taking charge in providing terrain information. Military planners knew this responsibility needed to be assigned, and the work load greatly expanded.

The resulting organization was TAC, which began not only as a small operation but an anomalous one. It was an operational element dealing with the here and now, while the other Fort Belvoir laboratories were working on some very long-term, high-risk projects. In the oft-cited "contest between life cycle and end run" approaches, TAC was to be a heavy hitter on the end run, off-the-shelf team.

In short order, however, TAC would grow to be a major part of USAETL's story, and be a good example of the laboratories' general reorientation toward both more field work and more hands-on initiatives in the years 1984-1988. While work on abstract and highly experimental initiatives continued, the rapid growth of TAC during these years points to more down-to-earth work for USAETL scientists.

Daunting task

In 1979, DMA became DOD's terrain analysis program manager, with TAC providing operational support. [Interview with Theodore W. Howard, Fort Belvoir, Va., 11 October 1984.[6]] By 1981, DMA had some large-scale terrain analysis capability, but it was unclear if it would be enough. The answer, as is evident throughout this period elsewhere in this history, is that it can never be enough.

Given the very nature of mapmaking and cartography, demand continually exceeded supply. Whatever advances were made in this very slow and tedious art — and USAETL played a direct role in many of those advances — the task of providing accurate and up-to-date terrain information was daunting.

Though laboratory scientists at USAETL pressed on with research designed to streamline many mapping tasks, it was apparent that truly automated mapmaking was still far in the future. Yet, new weapon research technology was creating an even greater demand for terrain information in digital format.

Creating Digital Topographic Data (DTD), in turn, was no less labor-intensive than traditional mapmaking. For all its flexibility, and for all the wonders that could be worked once it was in place, ideal DTD was not realistically expected to be universally available in the near-term. Studies carried out by USAETL itself proved as much.

Providing support for rapid deployment

In the near term, however, "shoot and scoot" commanders could not wait for terrain information in the optimal, digital form to arrive at some vague point down the road. Events had the habit of not complying with any scientific timetable. Army planners needed terrain information for the world's potential hot spots; and, more often than not, they needed it yesterday, as "rapid deployment" became the watchword of the day.

Accordingly, TAC was jump-started as an "operational side of the house" at USAETL to perform terrain analysis in response to the immediate worldwide requirements of a broad range of Army elements. [Interview with Theodore W. Howard, Fort Belvoir,

Va., 17 January 1991.[7]] The Army Assistant Chief of Staff for Intelligence validated and ranked TAC's efforts in order of importance, with funding and capability provided by the Chief of Engineers. TAC was to support rapid deployment, or fill in wherever needed.

Growing needs

Some areas of need had been obvious, such as terrain information in areas facing Warsaw Pact forces or in Korea, but providing support elsewhere required careful allocation of resources. USAETL and its allies were increasingly successful during the 1984-1988 time period in persuading military commanders that terrain information was a critical ingredient for success, but the flip side of this was an increasing appetite for terrain information products.

The demand for terrain information was particularly acute when DMA did not have the kind of product the field commander required. This proved to be the case often in these years — and, more and more often, TAC was asked to fill in.

Lesson two: Grenada in 1983

Just 10 years after the Middle East War, with TAC already up and running, the military was taught an object lesson in "Operation Urgent Fury" in Grenada. During this military action, no paper maps were available to the commanders for nearly the first 72 hours. [Maj. Gen. Robert Durkin, director, Defense Mapping Agency, *Defense*, 1988, page 21.[8]] And when those maps finally arrived, according to Maj. Gen. Durkin, they were of "limited utility."

While this history is not the place to recount the shortcomings of the Grenada operation, it is instructive that neither DMA nor TAC was in on the ground floor of planning for "Urgent Fury." DMA did not enter the picture until the operation was virtually underway. Predictable difficulties arose with maps and other terrain information requirements, with a great deal of attendant negative publicity. As a direct consequence, new procedures were adopted to bring in the terrain experts during early planning for all future operations. [Maj. Gen. Robert Durkin, director, Defense Mapping Agency, *Defense*, 1988, page 21.[9]]

Much as in the case of USAETL's Concepts and Analysis Division (CAD) (see Topographic Developments Laboratory (TDL)), TAC found its mission (and DMA's) more clearly defined after Grenada.

1. TAC'S MISSION

The authority and official framework for TAC's mission emanated from three documents: an Army Chief of Staff memorandum, an Army regulation, and a Department of Defense Directive. These documents were: Chief of Staff Memorandum, Army Departmental Terrain Analysis Requirements Processing (24 February 1977); AR 115-11, Army Topography (1 March 1980); and DOD Directive 4705.1, Management of Land-based Water Resources in Support of Contingency Operations (11 October 1983). But it can be argued that the fundamental authority derived from the growing appetite for "accurate, timely information about the terrain."

Much of this new emphasis came from the need to provide information for Intelligence Preparation of the Battlefield (IPB). It was TAC's specific role to bridge the gap between the broad-level support of DOD agencies (e.g., DMA) and the tactical support provided field commanders by engineer terrain detachments. It was, moreover, entirely in the tradition of USAETL acting as "godfather" to topographic units worldwide.

Providing this information gave TAC scientists some very specific chores between 1984-1988:

1. Preparing data bases of terrain conditions to support strategic and tactical contingency requirements.

2. Evaluating terrain and cultural data to determine their potential impact on military operations.

3. Maintaining an Army Central Terrain Intelligence File to support field source data requirements.

4. Providing technical guidance and advice to terrain teams in the field.

5. Producing special studies for unique Army terrain analysis requirements.

6. Maintaining a quick-response capability for crisis support and water detection.

7. Beginning in late 1981, collecting and producing land-based water resources information in support of worldwide military hydrology requirements.

8. Taking advantage of its location in the Cude Building, providing a "testing ground" for new techniques and equipment as they emerged from the other USAETL laboratories.

9. After 1 October 1986, transforming and/or enhancing DMA-produced DTED to meet Army requirements.

Expanding to meet Army needs

These growing responsibilities fueled the expansion of what had started out as a small part of the USAETL team. In the 1979-1983 time frame, TAC had been a late

arrival and a small part of the laboratories' focus. The Army's new emphasis on the importance of terrain changed all that.

In 1982, TAC was forced to reorganize and its manpower grew in subsequent years to meet its added responsibilities. In 1985, there was a "significant jump in manpower" to help the center meet growing demands. [Interview with Theodore W. Howard, Fort Belvoir, Va., 5 June 1992.[10]] TAC survived the major USAETL lab-wide reorganization of 1986, but did not pass the 1984-1988 period unaltered. By late 1988, TAC had to be expanded yet again, with several new offices being created to support emerging requirements for terrain and water resource products.

In general, the 1988 reorganization of TAC should be seen against the background of a growing demand for digital products, the need to modernize production techniques, and the growing water and AIS programs.

TAC modernization plan: 1987

For the bulk of the 1984-1988 period, there had been only three elements at TAC: two analytical divisions and the Program Support Division. The expansion to five elements mirrored the new importance of TAC and followed upon some hard thinking on how to organize TAC along more functional lines. [Interview with Allan E. DeWall, Fort Belvoir, Va., 5 June 1992.[11]]. In May 1987, a committee had met under the direction of Howard to "determine the future course of production efforts" within TAC. The resulting *Terrain Analysis Center Modernization Plan*,[12] written by Claudia Newbury, involved the whole TAC team and appeared in September of the same year, forming the basis of the reorganization of the center "from the ground up" in 1988.

The plan outlined a production posture for TAC that would upgrade the center's ability to support the Army's mid-term and long-term requirements — requirements that were unlikely to be met entirely by DMA. The reorganization also focused on modernizing current production processes and expanding TAC's capability for meeting the ever-increasing demand for new terrain and water resources products. [*Terrain Analysis Center Modernization Plan*, September 1987, page 1.[13]] Many of the recommendations and conclusions of the report were acted on in the reorganization of 1988.

Five elements at TAC: 1988

As part of its continual effort to stay state of the art, TAC's **Techniques Application Office** identified research and development requirements for terrain and water resources production procedures and user products. TAC specialists also kept an eye on potential breakthroughs in topographic and hydrologic equipment. In addition, this office continually worked to integrate new hardware and software into TAC's production system. This was TAC's interface with USAETL's elements, seeking the latest innovations to aid automation.

The **Terrain Studies Division** prepared terrain analysis data bases and MGI studies for the Army and DOD. The focus was largely on terrain features exclusive of water.

The **Military Hydrology Division** prepared hydrologic analyses, including water resources overlays, and managed the Corps' WDRT (see below). The division became an operational part of TAC in October 1988. Although the 1988 changes were seen as an "expansion and modernization" rather than a major change, [*Tech-Tran*, Vol. 13, No. 4, Fall 1988, page 8.[14]] these changes reflected the growing attention given to water needs in the 1984-1988 time frame.

Finally, the **Program Support Division** maintained a terrain and water resources data library to support both the MGI and hydrology programs, while the **Product Generation Division** (new in 1988) imported water resources data into the automated Water Resources Data Base (WRDB).

High in work unit priority

TAC's higher profile was reflected in USAETL's pecking order as well. By early 1986, TAC was second only to USAETL's Army Space Program Office work on the official list of work unit priorities. [In-house document, 14 October 1985.[15]] By 1988, TAC had tripled in size. [Interview with Theodore W. Howard, Fort Belvoir, Va., 23 May 1991.[16]]

And TAC was pushed to the front for good reason. Just as other elements at USAETL (e.g., CAD in TDL) were helping DMA meet the terrain data needs of the future, TAC was helping the Army meet the terrain data needs of the here and now.

Terrain analysis at TAC

In "filling the gap" between DMA and users in the field, TAC was required to tailor its products to specific needs. In fact, as TAC's William Brierly observed in 1985, the emerging work load had "no two jobs alike." DMA, by contrast, was doing data base products at strategic and tactical specifications only (i.e. 1:250,000 and 1:50,000-scale respectively). TAC might do a 1:25,000-scale or even a 1:12,000-scale product for an urban area if required. Indeed, in the early years in the 1984-1988 time frame, DMA itself approached TAC with an average of 35 requests that DMA could not meet. After 1986-1987, the Army would go directly to TAC to meet immediate needs, and TAC would cease handling DMA's overflow.

Meanwhile, out in the field with the terrain teams, the Army had needs it could not fill. But where TAC came into play, these were typically highly technical projects, such as a 100 map sheet, 10 topic project with each area (e.g., geology) requiring an advanced degree of scientific knowledge.

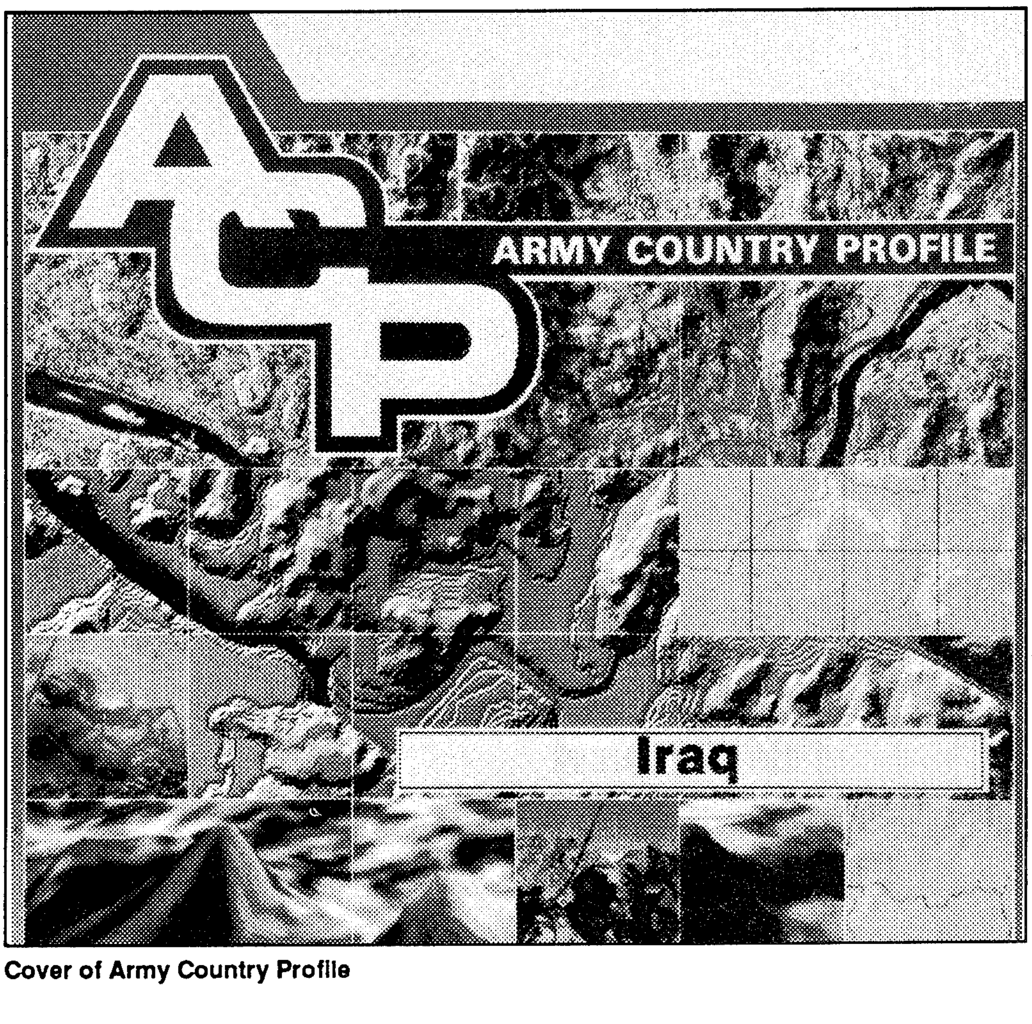
2. ARMY COUNTRY PROFILE WORK AT TAC

As early as 1985, TAC's projects had grown to nine programmed and five unprogrammed activities. The former included providing major support to the AIS program. The countries that were selected for analysis were chosen by FORSCOM and the requesting organization set guidelines for the type of information to be included.

In some cases, there was an obvious, urgent focus to the TAC studies, such as a Libya volume completed in November 1985. In other studies for AIS undertaken in the same year, such as the United Arab Emirates, Costa Rica and Mexico, the need was less driven by events.

Providing military geographic information

Of the five sections of the profiles, TAC would typically provide the military geographic portion. This section would help commanders pick out factors likely to affect troop cover, concealment, observation, cross-country mobility and avenues of approach. TAC analyses also would reveal what was known about the availability of construction materials, drop zones, high ground and



Cover of Army Country Profile

landing beaches for troops and equipment.

With this information added to the rest of the ACP, the commander had a complete planning document. The aim was to give trainers and planners of battlefield maneuvers a detailed, military geographic analysis of a country's terrain and its hydrographic features and infrastructure. [*Tech-Tran*, Vol. 6, No. 2 , Spring 1991, page 3.[17]]

Jump in demand

ACPs were done at the rate of roughly one a year until, at the close of the 1984-1988 period, plans were made to quadruple the output in response to a "big jump in demand." [Interview with Richard W. Dobie, Fort Belvoir, Va., 15 May 1991.[18]] This would require hiring 16 additional specialists. [Ibid.[19]]

But it already was clear by 1985 that TAC was growing well beyond its initial role as a small operational element at USAETL, particularly as this also was the year a Water Detection Response Team (WDRT) was established within the center to identify and evaluate water sources in support of operations.

3. RESPONDING TO NEED FOR WATER

Military planners had long known that water could be a major factor in any well-planned military operation, whether as an obstacle or conversely, as an aid to maneuver in battle. Fording streams or transporting heavy munitions had always been major tactical or logistic considerations. But in some cases, such as when waging war in arid regions of the world, water is not just a consideration, but an absolute requirement of battle.

Knowing where and how to find water had added value in such cases, as witnessed by real events in arid regions in the years just prior to the time frame 1984-1988.

Lessons of Egypt, Iran and Afghanistan

Howard cited the 1973 Arab-Israeli War as the key to the Army's new tactical appreciation of water. Dobie also pointed to the seizure of hostages at the U.S. Embassy in Teheran, Iran, and the Soviet invasion of Afghanistan, which did not result in any major U.S. military operations, but might well have. Both events put military planners squarely up against the water issue. In an arid region, a soldier could use as much as 20 gallons a day, and an estimated 15 percent of the water requirement was to be provided by well-drilling production.

All these considerations underlined the unfortunate fact that the military lacked the expertise and capability to locate and evaluate potential ground water sources. With vital U.S. interests in the region profoundly threatened, commanders discovered that it was "almost impossible to supply water to forces they might deploy to these arid regions." [*Tech-Tran*, Vol. 10, No. 2, Spring 1985, page 2.[20]] There was a clear need to begin some kind of water support program for such cases, particularly as the oil-rich area was likely to be an area of concern for U.S. interests for many years to come.

Directive from DOD: 1983

Traditionally, water data had come from USAETL, the U.S. Army Engineer Waterways Experiment Station (WES) and DMA in the form of hard-copy overlays. Experiences with the Rapid Deployment Force had proved the shortcomings of such manual methods. Following an Army Science Board Study, in October 1983, DOD issued Directive 4705.1, Management of Land-based Water Resources in Support of Joint Contingency Operations, ordering TAC to develop an improved, expanded and automated water resources data base.

The resulting report, titled User Requirements Analysis for the Worldwide Water Resources Data Base, spearheaded by Joel Frisch of the U.S. Geological Survey (USGS), appeared in January 1985, and quickly set things in motion. This fruitful cooperative effort with the Water Resources Division of USGS continued, and came to include the automation of TAC's bibliographical data base, a user requirements analysis for an automated WRDB, implementation of a relational data base, and ultimately a geographic information system as well as analytical support. In short order, a glossary of water-related terms was completed. Douglas Nebert lead the effort to program an automated data base, while TDL selected the system and software.

Water specialists needed

Fortunately, TAC specialists were hardly strangers to the Army's water needs. In 1985 alone, the center's analysts produced 120 water resource overlays in support of the U.S. Central Command, and it was part of TAC's mission to provide support to DOD's Military Hydrology program. But it was becoming increasingly clear that, for many cases, the Army needed something more.

The idea emerged for a roster of on-call specialists to find water. The abiding problem was that those who would most likely be called on for this task, the military terrain teams, had not been trained to locate and evaluate likely ground water sources for well drilling.

Members of DOD's Water Detection Response Team.

Forming a water team at TAC

As a direct consequence of this exposed shortcoming in the provision of water in contingencies, the Office of the Chief of Engineers moved to form a WDRT to be managed by TAC. Allan DeWall managed the team from its inception in spring of 1985. DeWall's immediate task was to find and assemble the required specialists. The goal was obvious but, as DeWall pointed out, the means to attaining that goal were not:

"...we had to go about getting it going in a different way. We were told we should look everywhere within the government to find people, and so we had to round them up in nontraditional ways." [*Lab Lines*, September/October 1986, page 7.[21]]

One "nontraditional" element was the fact that the WDRT was not only an unofficial entity, but an unfunded one as well. DeWall had to make sure that the customer requesting the team's services could cover the cost. Then, he had to scour the government for the needed team of experts.

1985 trial run in Honduras

Unorthodox funding notwithstanding, the WDRT was able to recommend well sites for a U.S. Southern Command terrain team training in Honduras during an exercise in winter of 1985. The team also estimated the well depths needed and provided information on the expected water quality. Finally, the specialists educated the Army well-drillers on special techniques for drilling and completing wells in the volcanic rock typical of the region.

That "prototype test" of the WDRT concept identified a number of problems that had to be worked out in setting up the team. Equipment needed to be added to the team inventory, including such mundane essentials as sun block lotion and medicine, and, as might have been expected, it was discovered that funding needed to be worked out much sooner. [Allan E. DeWall, John N. Baehr, and Laura C. Dwyer, Memorandum for the Record, 2 April 1985, page 7, Installation Files.[22]] But in the balance, the team called it "an excellent test" and

made plans for its first official mission in the Middle East that same year. [Ibid.[23]]

Operation Bright Star in 1985

Operation Bright Star in the Middle East, the WDRT's first official mission in 1985, was a "particularly difficult" one in that it involved finding water for a joint training exercise in an arid region. [Allan E. DeWall, Unpublished Draft of Water Detection Response Team release, Installation Files, unpaginated.[24]] To identify three well sites, the team had to interpret geological factors, analyze geophysical data and make complex technical judgments. They looked for faults, rock outcrops and other geologic formations, while also studying drainage patterns, vegetation and related terrain-based clues.

The result, however, showed DeWall and his team what they were up against. Of the three wells drilled on the team's recommendations, only one proved an excellent source of water. [Ibid.[25]] They had done their job, but it had not been easy. It was apparent that the typical Army terrain team would have found no water at all.

Art of detecting water

The point had been made, however, that finding water required bringing some very skilled specialists together. Conventional well-drilling teams were neither trained nor equipped to make most of the judgments made at Operation Bright Star.

Once the appropriate team had been assembled, the specialists used their data base development, remote sensing, and geophysical skills to go through maps and publications, while also evaluating available aerial, satellite and radar imagery. The results would lead the scientists to pick out two or three likely well-drilling sites, and have that information in the hands of the commander within two weeks of his initial request.

Typically, the team would send a volunteer unit to do an on-site geophysical survey. Thus, they could provide the commander a spot with good location, easy access, and perhaps even easily drillable rock material sitting atop a large aquifer. "In essence," said DeWall, "we showed them where to draw the 'X' on the ground." [Interview with Allan E. DeWall, Fort Belvoir, Va., 5 June 1992.[26]]

Success led to expanded role

From its formation in 1985, to the close of 1988, TAC's "quick water" team proved to be a success story. By 1988, DeWall cited a growing "recognition in the user community," saying that the military drilling detachments looked increasingly to the WDRT. [*Tech-Tran*, Vol. 13, No. 1, Winter 1988, page 5.[27]] A major reason was an improvement in the success rate, up to about 75 to 80 percent by late 1988 and "getting better all the time." [Interview with Allan E. DeWall, Fort Belvoir, Va., 5 June 1992.[28]]

Yet, that very success led to new responsibilities for the WDRT. Experience gained through the team's participation in military exercises in the Middle East, Central America, and the U.S. had shown that giving well-drilling units the likely location of water was often not enough. TAC's director concluded that the military units needed help in well-drilling operations and training in well completion techniques:

"They know how to operate wells but not really how to drill them. Sometimes they drilled right on down through, beyond the aquifer." [Interview with Theodore W. Howard, Fort Belvoir, Va., 23 May 1991.[29]]

Assistance was needed in determining the depth to water. DeWall cited learning to "interpret the cuttings" and "sensing the color change" as among the skills imparted. In doing so, the team compiled a list of government agencies, in addition to Corps districts, which had expertise in finding water. As if to again underline the role of synergy at USAETL, the Center for Remote Sensing also came to play a role in looking for water. DeWall tapped help from everywhere, but drew the line when he was actually approached by "professional" dowsers with forked sticks. [Ibid.[30]]

By the end of the 1984-1988 period, DeWall saw a growing realization that major sources of water could, like sources of oil, prove the cause of wars, not merely a required ingredient for effective battle. As a result, the U.S. Central Command placed increased emphasis on water resources data in the Middle East, Africa and parts of Asia.

4. TAC MODERNIZATION

In addition to water detection, TAC also gained new high-tech responsibilities. By 1986, TAC was supporting Army requirements for nonstandard format digital terrain data by means of a data transformation and data enrichment capability. This was just part of a continuing effort to modernize the center, taking advantage of its synergistic proximity to USAETL's less operational elements.

The 1987 *Terrain Analysis Center Modernization Plan* had acknowledged that many TAC products would be produced in soft copy in the long-term, and that mid-term production would "set the stage" for transition to soft-copy format. [*Terrain Analysis Center Modernization Plan*, September 1987, page 1.[31]] In the interim, however, TAC had to also render useful what DMA could provide.

Army Digital Data Support Facility (ADDSFAC)

In 1986, when FORSCOM fielded MICROFIX, a computer was put in the hands of the soldier for the first time. It was immediately apparent, however, that DMA's 9-track tapes needed to be transformed into VHS format to be of any use. To meet this emergency, TAC's Program Support Division created the Army Digital Data Support Facility (ADDSFAC).

FORSCOM funded ADDSFAC to provide transformed DTED to MICROFIX and, later, TerraBase users. The system proved "very effective," and came to be regarded by some as the unofficial training for the Digital Topographic Support System (DTSS). [Interview with Allan E. DeWall, 5 June 1992.[32]]

Digital terrain analysis production system

By 1988, the modernization effort centered in three major areas. The first was an unsuccessful investigation into the use of DTED Level 1 to produce Tactical Terrain Analysis Data Base surface configuration overlays. The second investigation looked into the map-scanning hardware and software for automated data input to a geographic information system, while the third initiative involved the design of a digital terrain analysis data base.

The latter two work areas led, respectively, to a procurement action for the automated data input equipment, and an agreement on a general design and a prototype TAC data base. TAC was indeed modernizing and "going digital," while still remaining very active operationally.

TAC support to battle simulation

Another area where TAC moved well beyond hard-copy maps was in its support to the Army Training Battlefield Simulation System (ARTBASS). This computer-based system was designed to allow battalion command groups to work their way through simulated combat situations in real time.

The ARTBASS concept was related to the development of airplane pilot flight simulators, especially in that it sought to enable its user to gain some realistic experience at less cost and with no danger. The ARTBASS trainee would be forced to make crucial military decisions, perform critical tasks, while dealing with a realistic "combat environment." TAC scientists were, of course, familiar with the concept through the terrain visualization work being done within USAETL in the Geographic Sciences Laboratory (GSL).

Supplying a number of data sets

The simulated environment required a computer-based system using an extensive mathematical model that could calculate line of sight, determine visual detection, simulate engagements, assess casualties with equipment and personnel, move units, and generate reports by the minute. ["Command Groups Train with Army Simulation System," *Tech-Tran*, Vol. 12, No. 2, Fall 1987, page 3.[33]] But it also required a digital data base which could involve any number of data sets.

With the digital terrain data "explosion of need" fully underway, DMA had more than enough to do trying to supply only standard products (see CAD in TDL). In fall of 1986, TAC began preparing analog terrain analysis overlays to support the digital terrain requirements of ARTBASS at the request of the Office of the Deputy Chief of Staff for Intelligence.

Problems with security

For all its promise, the TAC work for ARTBASS gradually ran into an unforeseen problem with security. The areas in which ARTBASS users wished to simulate battle were indeed areas where TAC had data in hand, but too often the information was classified.

Germany's Fulda Gap, for example, was a popular area for playing out war gaming simulation scenarios, but the data TAC would be compelled to provide included much secret information. Hence, for ARTBASS training uses, much of the requested data could not be provided. [Interview with Richard W. Dobie, Fort Belvoir, Va., 15 May 1991.[34]] In such cases, TAC's light was best left under the bushel. Though TAC offered to provide fictitious data for such critical hot spots, ARTBASS requests would fall off dramatically by the end of the 1984-1988 period. Real data were desired, but the classified data were not available to the customer.

ARTBASS had, nonetheless, been indicative of USAETL's increasing work load in nonstandard digital product production in areas where DMA could not furnish the required data support. It led, moreover, to TAC working on Simulation Network (SIMNET) technology, which would prove highly significant in subsequent years.

Growing operational work load

By 1988, TAC's work load included 174 terrain data bases, four country geography studies, numerous quick response terrain studies, 240 water resources map overlays, and more than 660 cells of tailored DTED. In addition to all this, TAC was developing an automated

water resources data base prototype for worldwide application (see below) and heading up the Corps' WDRT. [*Army Research and Development Organization of the Year Report for FY88*, page 1.[35]]

5. TAC PRODUCTS

Despite employing the same data collection analysis procedures, TAC terrain analyses varied according to user needs, often employing different form and content with both graphic and narrative material. But the bottom line was information, and as TAC's Jack Koll admitted, it had to be "still pretty much hard copy" since the digital dimension was "not there yet, except on the periphery." [Interview, with Jack Koll, Fort Belvoir, Va., 17 January 1990.[36]]

But no matter what the format, TAC analysts had to make sense of the varied sources of information about the geographic area in question. TAC specialists had to deal with both natural and man-made features that were likely to play roles in battle.

Depicting natural elements

In GSL's work on the Battlefield Environmental Effects Software (see BEES), the Environmental Design Guidance for Evaluation system (see EDGE), and elsewhere throughout this period, USAETL scientists evidenced a continuing interest in taking advantage of natural factors. In facing flashpoint situations in the here and now, TAC put even heavier emphasis on the natural elements present in any military situation.

During the 1984-1988 period, TAC specialists spent many long hours on surface configurations, soils, geology, vegetation, drainage, surface water, ground water, existing water supply facilities and climate. Knowledge of these factors could provide the field commander with the deciding edge in battle.

Depicting man-made elements

The terrain analyses produced by TAC varied according to users' needs, and thus, often included cultural and man-made features. It was a major consideration if operations were to take place in built-up areas, near highways, roads and railroads, or perhaps pipelines or ports, harbors and airfields. Electrical power lines and water storage facilities were other important elements.

Once TAC analysts had put together their information from as many sources as possible (most of them still manually produced), they turned to the evaluative portion of the study. TAC was not merely charged with assembling the data, though that in itself was a huge time-saver; TAC also had to sift and combine the data until it provided assistance to tactical decisions.

In real terms, this meant the TAC analysts churned out countless studies assessing cross-country mobility, mapping out landing and drop zones, and determining possible avenues of approach. Other projects involved evaluating line of sight, key terrain, and state-of-the-ground analyses.

Success story

Throughout this period of growth and modernizing, TAC had been able to meet many Army demands for terrain products in tight spots. This in turn meant more growth and the accompanying need for more modernization. TAC's ability to carry out its ever-growing mission is a major success story in the years 1984-1988.

In addition, as mentioned above, the bigger role for TAC mirrored an increasing role for USAETL in the world outside abstract research. The years 1984-1988 witnessed a turn to operational activities and thus, perhaps, to more end run (as opposed to life cycle) solutions at USAETL. Ever-growing TAC, with its eyes fixed on the here and now, played a major role in this reorientation.

Footnotes

1. *Army Research and Development Organization of the Year Report for FY88*, p. 1.

2. Briefing by Theodore W. Howard, Fort Belvoir, Va., 17 January 1991.

3. Interview, author with Theodore W. Howard, Fort Belvoir, Va., 24 May 1991.

4. Ibid.

5. Interview, author with Allan E. DeWall, Fort Belvoir, Va., 5 June 1992.

6. Interview, author with Theodore W. Howard, Fort Belvoir, Va., 11 October 1984.

7. Interview, author with Theodore W. Howard, Fort Belvoir, Va., 17 January 1991.

8. Maj. Gen. Robert Durkin, director, Defense Mapping Agency, *Defense*, 1988, p. 21.

9. Maj. Gen. Robert Durkin, director, Defense Mapping Agency, *Defense*, 1988, p. 21.

10. Interview, author with Theodore W. Howard, Fort Belvoir, Va., 5 June 1992.

11. Interview, author with Allan E. DeWall, Fort Belvoir, Va., 5 June 1992.

12. *Terrain Analysis Center Modernization Plan*, written by Claudia Newbury, September 1987.

13. *Terrain Analysis Center Modernization Plan*, September 1987, p. 1.

14. *Tech-Tran*, Vol. 13, No. 4, Fall 1988, p. 8.

15. In-house document, 14 October 1985.

16. Interview, author with Theodore W. Howard, Fort Belvoir, Va., 23 May 1991.

17. *Tech-Tran*, Vol. 6, No. 2, Spring 1991, p. 3.

18. Interview, author with Richard W. Dobie, Fort Belvoir, Va., 15 May 1991.

19. Ibid.

20. *Tech-Tran*, Vol. 10, No. 2, Spring 1985, p. 2.

21. *Lab Lines*, September/October 1986, p. 7.

22. Allan E. DeWall, John N. Baehr, and Laura C. Dwyer, Memorandum for Record, 2 April 1985, Page 7, Installation Files.

23. Ibid.

24. Allan E. DeWall, Unpublished Draft of Water Detection Response Team release, Installation Files, unpaginated.

25. Ibid.

26. Interview, author with Allan E. DeWall, Fort Belvoir, Va., 5 June 1992.

27. *Tech-Tran*, Vol. 13, No. 1, Winter 1988, p. 5.

28. Interview, author with Allan E. DeWall, Fort Belvoir, Va., 5 June 1992.

29. Interview, author with Theodore W. Howard, Fort Belvoir, Va., 23 May 1991.

30. Ibid.

31. *Terrain Analysis Center Modernization Plan*, September 1987, p. 1.

32. Interview, author with Allan E. DeWall, Fort Belvoir, Va., 5 June 1992.

33. "Command Groups Train with Army Simulation System," *Tech-Tran*, Vol. 12, No. 2, Fall 1987, p. 3.

34. Interview, author with Richard W. Dobie, Fort Belvoir, Va., 15 May 1991.

35. *Army Research and Development Organization of the Year Report for FY88*, p. 1.

36. Interview, author with Jack Koll, Fort Belvoir, Va., 17 January 1990.

Research Institute

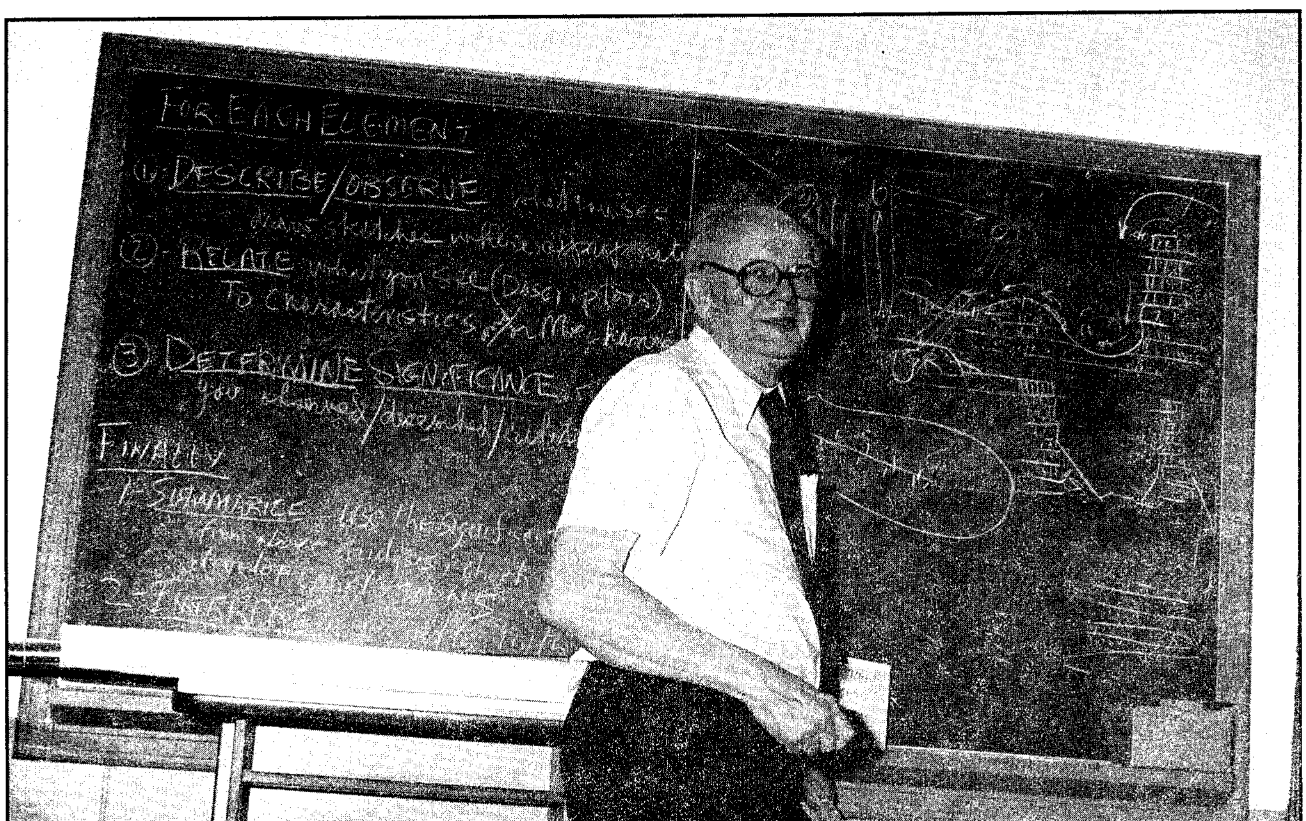
Between basic and applied research

Although the years 1984-1988 witnessed an increasingly "hands-on" approach at USAETL, the research-oriented approach still played a strong role at the laboratories. At the Research Institute (RI) in particular, work continued toward advancing the state of the art in the topographic sciences.

The scientists in RI not only sifted through emerging technologies for ways to speed along the work of other USAETL elements, but they also pursued research designed to expand the frontiers of science needed to maintain the Corps of Engineers' leadership in providing terrain information. Thus, the institute's work was carried out, in the words of RI's Alan Krusinger, "between basic and applied research." [Interview with Alan Krusinger, Fort Belvoir, Va., 26 March 1985.[1]] The scientists in RI advanced the state of the art in the areas of remote sensing, artificial intelligence and visualization techniques.

1. ROLE OF REMOTE SENSING

USAETL pursued many directions of research aimed at making better terrain analysis products and assuring that such products got to the field commander in a timely manner. The many advances made, however, were still predicated on the terrain information being there in the first place. All terrain information products, from the most yellowed map to the fanciest color



Imagery analyst Robert Frost

computer graphic, require an adequate data base. Yet, having that data base was by no means a "given" in many military situations.

There always have been parts of the world where access is limited, whether by political or military considerations, or the nature of the terrain itself. In addition, even where the terrain was neither forbidden nor forbidding, the process of extracting features was hard, specialized work and stubbornly resisted automating. It was all the harder then, to produce such terrain data from imagery derived from a vast distance. Remote Sensing is the discipline seeking to do this, involving varied technologies aimed at deriving terrain information from afar.

If the "primary thrust" of RI continued to be "extraction from aerial imagery," the methods used to extract that imagery evolved considerably during the years 1984-1988. This was in response to what USAETL's George Lukes called a "revolution in the diversity and performance of remote sensing acquisition systems." In other words, there were new ways to see things from afar. And in some cases, seeing from afar was the only source of terrain information.

Center for Remote Sensing

The Center for Remote Sensing (CRS) first appeared on the Fort Belvoir scene in 1970, when the Photographic Interpretation Research Division of the U.S. Army Cold Regions Research and Engineering Laboratory transferred into the Geographic Sciences Laboratory (GSL) at USAETL. In 1974, it became CRS within RI, while retaining its focus on air-photo interpretation, all-source imagery and remote sensing technology.

When remotely sensed data were the only available source of information, what was the best a commander could hope for? USAETL's CRS sought to improve upon the answer to this question.

Legacy of Robert Frost

Looking back into the years of the 1970s and early 1980s, one sees CRS's emphasis on investigations involving geodesy, point positioning, and extraction of terrain information from photography, radar, thermal and Landsat imagery. Much of that work took its direction from the tried and true formulations of storied USAETL imagery analyst Robert Frost who, for many years, defined the boundaries of the discipline. Frost had distilled three principles of photo analysis:

1. An air photo is composed of pattern elements that indicate conditions, materials and events.

2. Like materials and conditions, given a like environment, yield like patterns; conversely, unlike materials and conditions yield unlike patterns.

3. The information gained will mirror the competence of the analyst.

The third principle clearly reflects the conviction of a tradition-minded element within CRS that did not expect to see automated interpretation of imagery anytime soon. Frost himself had never been an optimist regarding near-term feature extraction help from computers. Similarly, though at the cutting edge of any number of new ways to multiply the varieties of remotely sensed imagery, CRS's Dr. Jack N. Rinker continued to stress that "skill, experience, judgment and knowledge" were always likely to be the essential ingredients in imagery analysis. [Interview with Dr. Jack N. Rinker, Fort Belvoir, Va., 20 September 1984.[2]]

With this assertion, however, Dr. Rinker was restricting his verdict to imagery automatically derived from remote sensing for the purposes of general terrain information. In the wholly different realm of use for targeting, he foresaw vast potential "beyond any previous remote sensor" for a type of data — hyperspectral imagery — developed during this period. [Ibid.[3]] It would be fair to say, however, that opinions varied on the degree to which even extracting data for targeting could be automated in the near future.

Background to CRS

Remote sensing allows one to secure terrain information where one, for whatever reason, cannot go. With the global responsibilities of the U.S. military, such places have never been lacking. Not surprisingly, the U.S. military has a long history of interest in remote sensing.

The clearest line to current radiation collecting remote sensing leads back to the late 1940s and 1950s, when the Army joined other groups in seeking ways to improve techniques for target selection and mapping conditions such as camouflage, vegetation type, vegetation stress, soil moisture, flood damage, wetland boundaries, etc. Scientists used "multiband photography," dividing the photographic portion of the electromagnetic spectrum into narrower bandpasses, to aid some forms of targeting and change detection.

Dr. Rinker saw these efforts as "the first steps" in modern remote sensing systems development. [Dr. Jack N. Rinker, "Hyperspectral Imagery — What is it? — What can it do?," paper presented at the U.S. Army Corps of Engineers' Seventh Remote Sensing Symposium, 7-9 May 1990, Portland, Ore., page 5.[4]]

Dr. Jack N. Rinker and Phyllis Corl

Evolving spectroscopy

There remained the matter of getting the analyst the best possible information. RI researchers were seeking the optimal data base that could be put together from remotely sensed imagery. For years, CRS had sought to answer the question of how to best extract terrain information from afar. These years would witness some real advances in this area accomplished through employing new spectroscopy techniques.

Spectroscopy is the use of very precise spectral information (referred to as "hyperspectral" imagery) and the combining of information from different segments of the electromagnetic spectrum (called "multispectral" imagery). The segments of the spectrum are called "bands."

Building on Landsat's multispectral scanner

With the use of satellites, came the Landsat Multispectral Scanner (MSS), which reflected sunlight in four broad bands, two of them visible, two of them infrared. This led, in turn, to the Thematic Mapper (TM) with six bands in the reflected solar region, and one band in the thermal infrared. The trend continued with further extensions into the thermal infrared region with Airborne Very-High Resolution Radiometer (AVHRR), and the airborne Thermal Infrared Multispectral Scanner (TIMS).

The point, however, was that these new techniques were finding more and more "signatures" in what they were scanning. Separating out more and more data

meant knowing more characteristics of what was being scanned, and, hence, by adding up all these traits, knowing what it was likely to be.

Much of what was being done, observed Dr. Rinker, involved finding the data, whether thermal or microwave, and deducing terrain information from it. [Interview with Dr. Jack N. Rinker, Fort Belvoir, Va., 26 November 1991.[5]] Throughout these years, Dr. Rinker remained firm in his view that extracting general terrain information this way would require an "interactive system," with an expert human firmly in the loop. Targeting, we shall see, was a different matter, with potential for some automation.

From AIS to AVIRIS

The next step came with the Jet Propulsion Laboratory's development of the Airborne Imaging Spectrometer (AIS), a system that "greatly altered the existing concepts of multispectral remote sensing." [Dr. Jack N. Rinker, "Hyperspectral Imagery — What is it? — What can it do?," paper presented at the U.S. Army Corps of Engineers' Seventh Remote Sensing Symposium, 7-9 May 1990, Portland, Ore., page 5.[6]] The AIS recorded reflected solar energy in 128 channels, or images. Writing in 1985, Dr. Rinker and fellow CRS researcher Phyllis Corl had correctly predicted that techniques based on spectral data would "improve significantly in the future as satellites with more and narrower spectral band passes are launched." [Dr. Jack N. Rinker, Phyllis Corl, "Air Photo Analysis, Photo Interpretation Logic and Feature Extraction," USAETL-0329, June 1984, page 6.[7]]

This view was vindicated when the AIS evolved into the Airborne Visible and Infrared Imaging Spectrometer (AVIRIS), with some 220 raw data channels or images. At this point, because of the narrowness of the bands, systems like AIS and AVIRIS came to be called "hyperspectral" to differentiate them from the broad band systems such as MSS, TM, SPOT, etc. CRS researchers J. Ponder Henley, Alan Krusinger, and Melvin Satterwhite joined John Eastes in looking for ways to put these advances to Army use. USAETL initiatives included:

- Developing classification and analytical software;

- Collecting extensive field and laboratory spectral measurements of soil, rocks, vegetation and man-made materials;

- Maintaining (with the U.S. Geological Survey) a series of instrumented test sites that collect around-the-clock measurements of target/background radiation characteristics and concurrent meteorological conditions [Rice, J.E.; Krusinger, A.E., "A New and Extensive Thermal Contrast Data Base," Proceedings — AVIRIS Specialty Group on Targets, Background Discriminations, Vol. II, 1985, pp. 1-5.[8]]

Dr. Rinker credited the resulting data base with supporting empirical modeling, assisting target recognition, and furthering digital analysis techniques for hyperspectral imagery. [Dr. Jack N. Rinker, "Hyperspectral Imagery — What is it? — What can it do,?" paper presented at the U.S. Army Corps of Engineers' Seventh Remote Sensing Symposium, 7-9 May 1990, Portland, Ore., page 22.[9]] Though self-admittedly a skeptic with regard to so-called breakthroughs diminishing the role of the skilled interpreter of remote sensing data, Dr. Rinker considered AVIRIS a "big help" in these years. [Interview with Dr. Jack N. Rinker, Fort Belvoir, Va., 26 November 1991.[10]]

More than classical terrain information

The combining of the new sources of spectral information stood to greatly enlarge the scope of operations in seeking terrain information, providing far more than classic terrain information. CRS scientists analyzed signals to detect thermal differences and chemicals betraying evidence of pollutants.

Researchers also found ways to determine the mineral content of surface and subsurface materials, and to record changes in vegetation. Finally, they developed techniques making it possible to pick out with accuracy man-made features such as structures and hidden fortifications.

Terrain information approaches

Some of the techniques worked out in these years permitted precise identification of man-made features. Others, such as pollutant or vegetation change detection, had a still wider application to Corps environmental responsibilities.

Though CRS scientists hesitated to draw a precise line between the two, it was generally felt that the methods best tailored for identification of man-made features showed promise for digital techniques, and hence, possible automation; while others specifically suited to extracting general terrain information would require expert interpretation for a good while yet. [Interview with Dr. Jack N. Rinker, Fort Belvoir, Va, 26 November 1991.[11]] The goal, however, was a shared one: seeking the "unmistakable fingerprints" of a "unique spectral signature." [Ibid.[12]]

Avoiding duplication of effort

The increasing number of methods used to derive terrain information from space was mirrored by an increasing number of agencies interested in having access to that information. The very success of the new techniques themselves meant that there was a possibility that potential users might be duplicating each others' efforts. Here, as in many other areas, USAETL matched its efforts at increasing sophistication with efforts to be as economical as possible in the process.

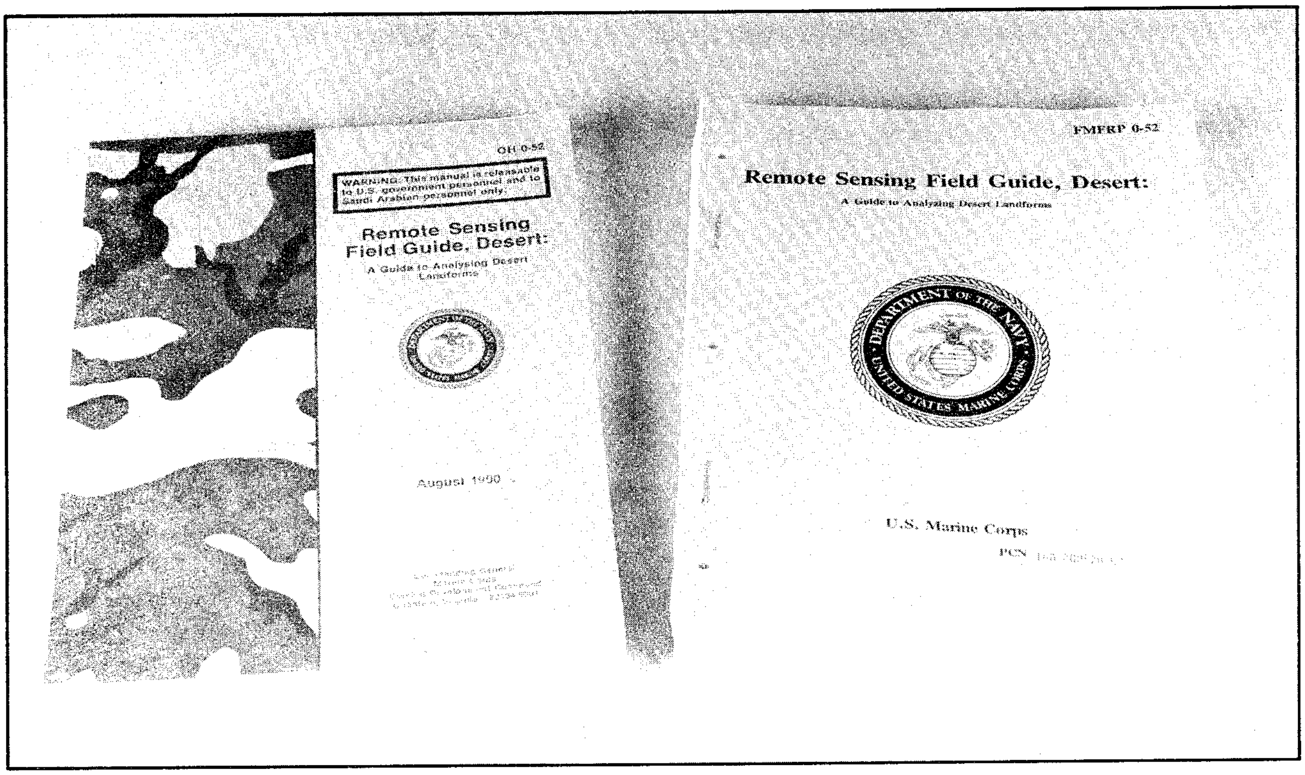
Scientists at USAETL were aware, for example, that the U.S. Geological Survey (USGS) had been monitoring geometeorological conditions in different types of desert (e.g., see McCauley, J.F., Breed, C.S., Helm, P.J., Billingsley, G.H., and McCauley, C.K., "Remote Monitoring of Processes That Shape Desert Surfaces: The Desert Wind Project," *U.S. Geological Survey Bulletin 1634*, 1984[13]). In Arizona, in particular, USGS had been making effective use of data relayed by satellite from solar-powered "Geomet" stations, automated platforms tied to an array of sensors collecting data around-the-clock.

Such data were of use to those scientists involved in studies of wind erosion and other surface geologic processes in deserts. Dr. Rinker and his USAETL colleagues thought that these measurements of boundary-layer atmospheric and geologic conditions might be of considerable use to the Army. The same data might be put to different uses.

CRS had its own experience in evaluating a variety of remote sensors and image-analysis techniques. Its instrumented test site (temperate as opposed to arid) had 5 years of measurements by the end of 1988. But much of the shared labor had taken place in subhumid regions, and a substantial part of CRS research had, where possible, been applied to improving techniques used by the Army to get information on desert terrain.

Army in the desert

While the USGS desert studies were intended to track surface geologic processes, especially wind erosion, and landforms that develop in such cases, the U.S. Army's focus was on any such information allowing it to operate better in the desert. The Army, which anticipated the requirement to operate in various types of deserts, wanted information pertaining to natural hindrances to cross-country movement, selection of aircraft landing sites, cover and concealment, camouflage, dust generation, and location of usable water. To that end, CRS had been evaluating a variety of remote sensors and image analysis techniques in such regions with an eye toward using these techniques to give the Army better terrain information in the desert. The question, however, was whether there might not be some improvement (and some economizing) by sharing data with USGS.



Remote Sensing Field Guide, Desert

Interagency meeting in 1984

Dr. Rinker and his team needed to put their heads together with USGS scientists to explore their "complementary research needs." To that end, USGS and USAETL-CRS came together for a workshop with "some of the leading workers in desert processes to exchange information on current programs, to establish general limits of knowledge, to identify areas of research and their priorities, and to discuss the applications of results to civil and military problems." [John F. McCauley and Dr. Jack N. Rinker, "A Workshop on Desert Processes, 24-28 September — Report on the Conference," *U.S. Geological Survey Circular 989*, page 1.[14]] The conference took place in a get-it-done atmosphere, rather than an academic one full of formal papers. There was, by all accounts, a "forum for lively discussion about selected topics." [Ibid.[15]]

CRS contributions

The contributions of USAETL participants in this key conference reflected CRS pursuits in the 1984-1988 period. Phyllis Corl handled the advance planning, while Dr. Rinker discussed instrumented field sites, Melvin Satterwhite vegetation, Judy Ehlen chemical weathering, and Ponder Henley the military aspects of desert processes. These initiatives, together with the cooperative effort with USGS, produced a number of useful objectives and recommendations, none of them more important than the decision to initiate collaborative research. [Ibid., page 5.[16]]

Looking back on these years, Dr. Rinker saw a turning point in this Flagstaff, Ariz., meeting. The Workshop on Desert Processes, he recalled, found a "90 percent overlap" of the agencies' requirements. [Interview with Dr. Jack N. Rinker, Fort Belvoir, Va., 26 November 1991.[17]] This, in turn, led to the further conclusion that there also was a great common research interest with the National Oceanic and Atmospheric Administration (NOAA), U.S. Food and Drug Administration (FDA), and U.S. Department of Agriculture (USDA).

Remote Sensing Field Guide, Desert

One of the products of all the desert research was an improved capability to use image patterns as indicators of terrain identities and conditions. Dr. Rinker's team worked throughout this period with USGS on what was to become the *Remote Sensing Field Guide, Desert*. The researchers classified desert features, and produced summary sheets describing the features and their origins.

The guide then sought to relate the characteristics with regard to key engineering and military needs. Using their photo interpretation and related skills, the remote sensing specialists began developing pattern indicator sheets showing the feature under study in photos, or thermal and radar imagery from airborne and satellite systems. Along with this, the guide was to provide a description of the meaning of the pattern for engineering and military operations. Eventually, similar guides were foreseen for other climactic regions, but subsequent events rendered the choice of desert an auspicious one.

2. ARTIFICIAL INTELLIGENCE AND IMAGERY RESEARCH

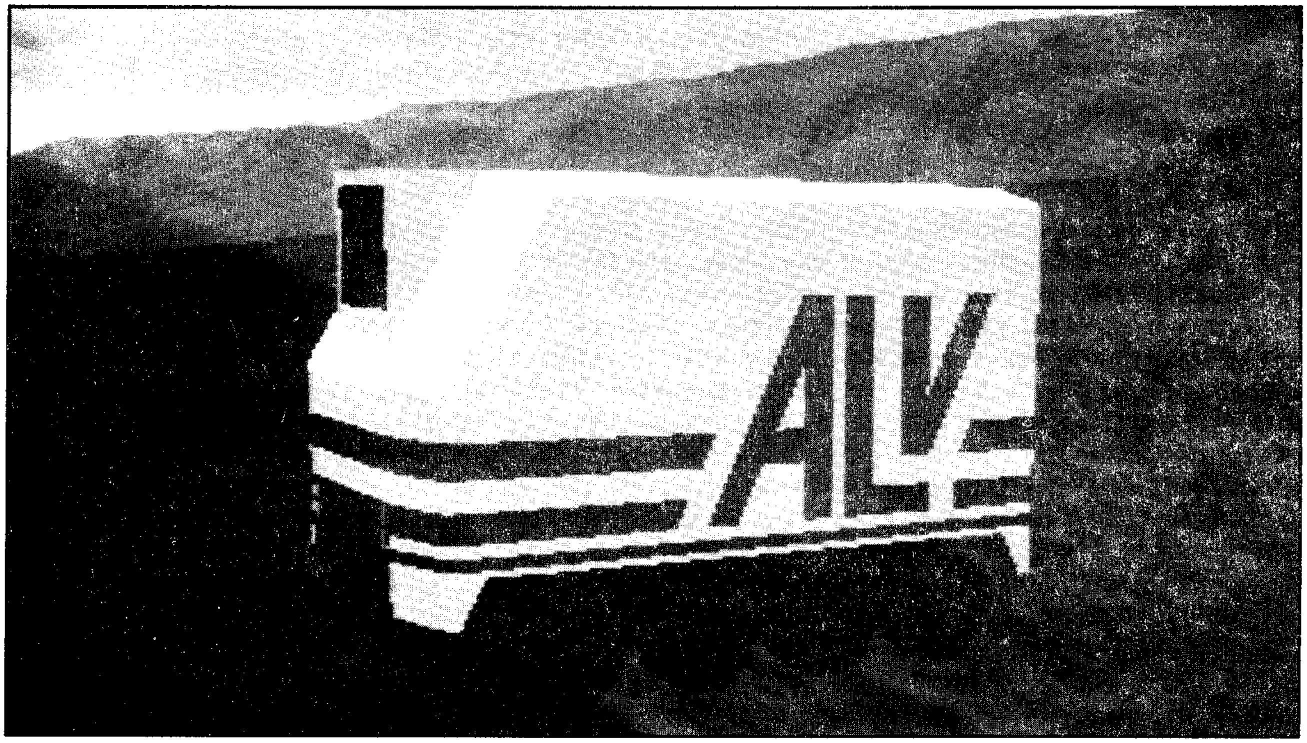
The years 1984-1988 saw many developments in remote sensing techniques, allowing the Army to gather terrain information from new sources by means of new and better techniques. With all these new kinds of data coming in, it became urgent for USAETL scientists to find better ways to assimilate, analyze and portray the ever-growing mass of terrain information from these new sources.

One promising possibility was the use of Artificial Intelligence (AI) so that computers could automate the use of terrain data. It was thought that AI could provide automated help in some tasks, allowing battlefield planners to work faster and with fewer people. This, in turn, would support USAETL's continuing effort to find ways to use the terrain more effectively.

Toward automated terrain reasoning

If the modern battlefield commander was expected to make full use of the terrain, he needed not only the standard topographical map, but a host of terrain products depicting transportation, soil types, vegetation and more. Such information was vital to Intelligence Preparation of the Battlefield (IPB), where it was to be combined with doctrinal information about the battlefield, the disposition of the enemy and friendly forces. This kind of "terrain reasoning," a marriage of terrain analysis and military doctrine, was a prime candidate for automation in the years following 1984.

The rationale for seeking help in this area was obvious. The proliferation of terrain information data sources (see, for example, Remote Sensing) stood to overwhelm human capacity to use it effectively. USAETL scientists recognized a "human inability to accurately retain and manipulate a number of variables simultaneously" and admitted that, for humans, "some complex tasks could be next to impossible to complete." [*1991 Organizational Activities*, pp. 49-50.[18]] Help would have to come from new quarters, such as imagery research and artificial intelligence within USAETL.



The Autonomous Land Vehicle represented a new generation of "machine intelligent technology."

Extracting information from aerial imagery

The introduction of new sources of terrain information did not eliminate the military's reliance on humans to extract terrain information from all-source imagery. Here, as elsewhere, the familiar "mapmaking bottleneck" remained a problem, predicated on the fact that such work is time-consuming, error-prone and costly. This, in turn, led to countless efforts to automate the process, with decidedly marginal results.

Prior to this period, RI's imagery researchers had concentrated on trying to automate aspects of extracting terrain information from synthetic aperture radar. The Advanced Digital Radar Imagery Exploitation System (ADRIES), a target screening aid, was one result of this effort. By 1986, combinations of image processing and expert systems technology had evolved to the point where built-up areas, boundaries, forests, fields, runways and bodies of water were being successfully extracted. [*FY86 U.S. Army Laboratory of the Year Report*, page 22.[19]]

Work in artificial intelligence

On 4 March 1982, the Center for Artificial Intelligence (CAI) officially replaced the Center for Coherent Optics at USAETL. The center had long carried out research in Hybrid Optical/Digital Image Processing, Laser Beam Recorder Technology, Voice Interactive Systems Technology, and Computer-Assisted Photo Interpretation Research (CAPIR). Such work continued, but following the lead of Dr. Robert Leighty, the now renamed center added new work units dealing with Artificial Intelligence Research and a Robotic Reconnaissance Vehicle Demonstration.

The creation of the center was followed by a massive retraining of personnel under the direction of Dr. Leighty and team leader Anne Werkheiser. Col. Edward K. Wintz, USAETL's commander in 1984, saw the change this way:

"Three years ago Artificial Intelligence/Robotics was a gleam in a few eyes at USAETL. Today, scores of researchers are active in the arcane world of LISP, Fuzzy sets and expert systems." [*FY84 Laboratory of the Year Report*, page 3.[20]]

In short order, CAI had an in-house artificial intelligence test bed to explore machine vision capabilities, and the center was working in concert with the Defense Advanced Research Projects Agency (DARPA) in this area.

Autonomous technologies

Another aspect of CAI work with DARPA in this period was with the Autonomous Land Vehicle (ALV), a machine demonstrator pulling together new capabilities from the evolving technology base. Using artificial

intelligence, computer science and advances in microelectronics, ALV was to spearhead a new generation of "machine intelligent technology" envisioned under DARPA's Strategic Computing Program. George Lukes and his fellow CAI scientists sought to use their expertise in computer vision techniques to support the ALV initiative.

Specifically, the ALV contractor, Martin Marietta, started with ALV in an empty parking lot and worked out programs allowing the vehicle to elude parking pylons. The plan then proceeded, through many steps, to navigation at greater speeds along roads. These capabilities, though modest at the outset, were autonomous ones — with no man in the loop. This distinguished ALV essentially from contemporary Army Terrain Analysis Demonstrator (TAD) vehicles which could do much more, but were remote-controlled by a human.

Landmark demonstrations in 1985 and 1986

ALV was demonstrated twice in 1985: in May on a straight section of road, when it navigated 1 kilometer of secondary road at a constant speed of 5 kilometers per hour; and in December, when it mastered its first curve at 3 kilometers per hour and drove 5 kilometers of straight paved road at 10 kilometers per hour. In June 1986, the vehicle's increased speed and capabilities were showcased in a "perfect demonstration" at the Martin Marietta facility. [*Tech-Tran*, Vol. 11, No. 3, Summer 1986, page 3.[21]]

Plans for future

The practical aim of ALV research resembled that of the robotic TAD. The difference was that the ALV was envisioned as a fully autonomous vehicle, gathering information, detecting contaminants, transporting weapons, carrying supplies and performing other combat-related roles. The soldier would one day be spared that labor and peril. [Ibid.[22]]

Though neither the robotic TAD, which also had close ties to USAETL (through Bruce Zimmerman at GSL's Intelligent Systems Group), nor the ALV would remain exclusive USAETL responsibilities through the 1984-1988 period, both projects retained ties to the laboratories. Just as USAETL researchers stayed in touch with TAD after it was transferred to the U.S. Army Tank-Automotive Command (TACOM) in 1984, AI scientists kept close tabs on ALV research after it had been transferred to various universities.

Much of this labor continued, moreover, in the work of the Autonomous Technologies Division (ATD). In addition to work in computer vision, digital mapping, and autonomous navigation, ATD continued to provide technical support to DARPA and other government programs concerned with semiautonomous and autonomous systems.

Work in the area of computer-assisted vision continued. In 1988, autonomous tech specialists delivered a state-of-the-art, 3-D computer graphics work station to the Army Research Institute to help determine the best use of advanced commercial technology to meet land navigation needs, and to obtain user feedback. [USAETL 1988 Annual Historical Summary, Installation Files, page 2.[23]]

Establishing a link to expert system

Just as with ALV, the AI researchers did not cease trying to bridge the gap in the automated linkages that connect an expert system query and the data waiting in the geographic information system (GIS). [*1991 Organizational Activities*, page 49.[24]] The problem was that a human — usually a skilled one at that — was still needed to identify terrain features. Indeed, AI researcher John Benton said that skeptics like Dr. Rinker were "rightfully doubtful about a computer being able to do the things they do." [Interview with John Benton, Fort Belvoir, Va., 14 January 1992.[25]]

In a sense, yet another form of the "mapmaking bottleneck," so much an abiding part of USAETL's story through the years, was manifesting itself. A human was still in the loop.

Digital radar imagery exploitation

Significant progress was made, however, on systems using expert systems technology in concert with radar image analysis and feature extraction. Researchers experimented with several automated feature extraction techniques, including combinations of image processing and expert systems. By 1986, there was real progress in successfully extracting built-up areas, boundaries, forests, fields, runways and bodies of water. [*FY86 U.S. Army Laboratory of the Year Report*, page 22.[26]]

The ADRIES was a major related initiative (see Space Programs Laboratory (SPL), page 77.), using an end-to-end integrated processing capability to fashion an intelligent tactical target screener. This system, under development for DARPA and IPB, selected target-rich areas for the special attention of the analyst.

Imagery research: beyond synthetic aperture radar

While the ADRIES technology remained dependent on data derived from synthetic aperture radar, the institute's imagery research specialists tried to apply the evolving automated and semiautomated feature

extraction techniques to other varieties of remotely sensed image data. After all, above and beyond radar, terrain also could be seen (optically) by the eye, sensed (thermally) as emitting heat, and scanned (hyperspectrally) by multiband sensors.

Hoping to provide a baseline for future successful techniques, RI scientists pursued a wide assortment of new methods for processing a variety of imagery. By the end of 1988, researchers were approaching the problem of extraction on several fronts. Some scientists attacked the problem using image processing techniques, pattern recognition and computer vision, while other scientists joined SPL in exploring potential gains from tracking the intensity distribution of the spectrum of remotely sensed electromagnetic radiation (see SPL page 77).

In addition to exploring these new sources for automatically extractable remotely sensed data, the imagery research team also considered "environmental" applications of their techniques. Any system capable of automatically detecting change in the landscape had a potential civil works as well as a military application. The Corps of Engineers, with its history of responsibility for river, harbor and wetlands could be expected to consider change detection imagery research for use in the area of environmental control as well as disaster assessment.

Saving time through AI

Notwithstanding all the advances in the mid-1980's, computer scientist Benton remained conservative in his expectations for some AI research. He emphasized, for example, that the goal of much of the work in AI was not so much teaching a machine to do what a human cannot, but rather "getting it to do what we lack the time to do." [Interview with John Benton, Fort Belvoir, Va., 14 January 1992.[27]] This period saw the AI Division work on several initiatives with that aim.

Automated detection of moving vehicles

The ALV independent contractor, Werkheiser and other AI specialists participated in a long-term program involving "target motion tracking." In cooperation with Dr. Thomas Huang at the University of Illinois, AI specialists sought to develop passive sensors systems able to detect motion and anticipate destination automatically. Such a system was envisioned as an aid in target acquisition (i.e., spotting something moving) and in target tracking (i.e., predicting where it would end up).

In a series of papers published in the years 1984-1988, USAETL's researchers explored advances in motion detection. The USAETL concept was unique in that it made use of a rigorous photogrammetric model, a mathematical model mated to real-world geometry. Such software had potential applications to robotic vehicles or even ALV-derived mobile sensor technology. [Ibid.[28]]

AI in route planning

Another vehicle-related AI initiative involved developing software capable of planning the optimal route between two points. Benton started this work in-house in 1984, yet was soon able to demonstrate a "Multiple Route Planner." During the 1984-1986 time frame, Benton took map data and applied AI algorithms in perfecting his route planner. The initiative became a part of the core program in 1986.

Using AI to plan routes posed some formidable obstacles. The primary one consisted in the fact that doubling any distance squared the number or points on the grid. Benton spoke of the difficulty inherent in dealing with anything more than a short distance, and spoke of facing a possible "computational meltdown" or "exponential explosion." When greater distances were attempted, the route planner's time requirement "mushroomed." [Ibid.[29]] To address this problem, Benton presented a paper to the International Society for Optical Engineering in 1988. He highlighted a "hierarchical," expanded version of the route planner. ["Hierarchical Route Planner," Proceedings of SPIE (International Society for Optical Engineering), Vol. 937, Application of Artificial Intelligence VI, 4-6 April 1988, pp. 428-434.[30]]

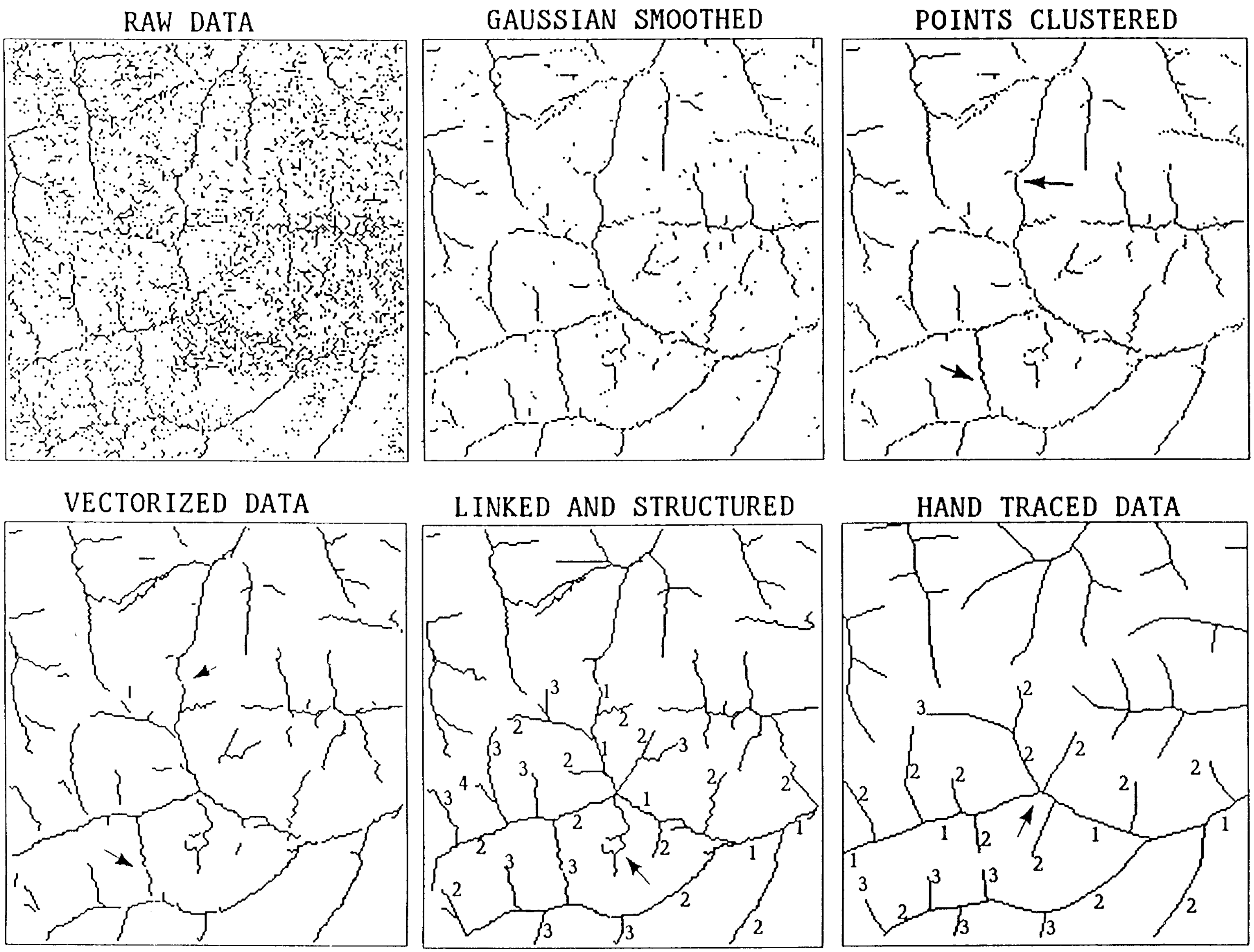
This Hierarchical Route Planner (HRP) generated graphs in order to do cross-country mobility planning over a longer distance. As a graph and grid-based (as opposed to mere grid) planner, the HRP used the graphic tier to plan approximate routes over long distances, and the lower level grid planner to plan the precise paths between the nodes of the graph level route. Work continued on making the system more robust. [Ibid.[31]]

Automated delineation of drainage patterns

Researcher Benton saw another "major success" scored in the area of automating the extraction of drainage patterns. This was thought to be "the first working application of AI technology to topography." [USAETL 1988 Annual Historical Summary, Installation Files, page 2.[32]] Using elevation data generated from the stereo compilation work of F. Ray Norvelle (see SPL page 77), Dr. William Seemuller developed a method to automatically extract drainage patterns.

A nonprofessional can easily imagine, at least theoretically, that knowing the elevation data in an area

DRAINAGE DELINEATION



might yield further information such as the drainage patterns. Water, after all, flows downhill, and elevation data provides the probable ups and downs. During 1984-1988, the capability to predict drainage patterns was developed to the point that the software was incorporated as a Tactical Decision Aid (TDA) in USAETL's AirLand Battlefield Environment (ALBE) initiative. Automated drainage predictions had a twofold use, helping to avoid potential flash-flood areas, as well as potentially helping to select air avenues of approach. Not surprisingly, the program also quickly found its way to the Terrain Information Extraction System (TIES), a system being developed at GSL to (among other things) extract Digital Topographic Data from available remotely sensed imagery.

3. TERRAIN VISUALIZATION

Another imaginative use of elevation data within RI was Michael McDonnell's effort to generate perspective views by means of software developed by the AI Division. McDonnell was addressing the old dilemma posed by the fact that the ability to read a conventional topographical map was a skill not present in every commander. McDonnell likened it to having or not having the ability to carry a tune, and he looked for ways to use computers to compensate for not having this "knack" with respect to maps. The relatively modern acceptance of the importance of knowledge of terrain in battle made it doubly important to make full use of what one had.

McDonnell looked for a way to drape either aerial photographs or electronic map data over the terrain. In so doing, he found he could develop realistic-looking displays that provided easily intelligible perspective views. He also developed applications that made use of a high-speed parallel computer to create terrain fly-throughs. In these, as with the perspective views, there was no map-reading "knack" required to get an idea of the terrain.

A generic solution

McDonnell's software made it possible to produce very realistic perspective scenes using a relatively simple computer. It had the further advantage of making use of vendor-independent standards that ensured portability to a large number of computer systems. In this way, it must be seen as one of the many USAETL efforts to find a "generic," economical solution to a high-tech problem.

Some researchers even thought this "scan line" approach accomplished some things in a simpler way than the "polygon" approach being pursued by GSL's Computer Image Generation (CIG) specialists during this same period. It should be pointed out, however, that the more ornate CIG software allowed many things to be done (e.g., incorporating structures and vehicles into the picture) that this system did not in its current state of development. On the other hand, CAI's terrain visualization software already showed promise for use in recommending sites for missile batteries and command posts.

Learning from complexity

AI's Werkheiser summed up the importance of this work on "easy" visualization by observing that "one picture was worth a megaword." [Interview with Anne Werkheiser, Fort Belvoir, Va., 16 April 1992.[33]] She allowed, however, that little else of what AI attempted could be described as easy. Even the way a central dilemma was described was daunting: working to "eliminate the 'disconnect' between the GIS and the expert system." [Interview with John Benton, Fort Belvoir, Va., 14 January 1992.[34]] Benton emphasized the difficulty in "going all the way from conceptualization to real-world data" as being "essentially similar to trying to automatic feature extraction from a photo." [Ibid.[35]] Few at USAETL needed to be told how complex a proposition that was.

Verdict of the future

So it was that scientist Werkheiser described AI work as "learning from writing computer programs" and doing research "to get the computers to do the things that are trivial for people," such as recognizing speech and understanding pictures. She even considered a "major contribution" of AI to have been "showing how complex these matters are." [Interview with Anne Werkheiser, Fort Belvoir, Va., 16 April 1992.[36]]

With the exception, perhaps, of CRS, the labors of RI are hard to judge, especially insofar as the final verdict on them will only be rendered in the future. High-risk research had, however, proven itself at the laboratories in the past, and stood to do the same in the 1990s and beyond.

Footnotes

1. Interview, author with Alan Krusinger, Fort Belvoir, Va., 26 March 1985.

2. Interview, author with Dr. Jack N. Rinker, Fort Belvoir, Va., 20 September 1984.

3. Ibid.

4. Dr. Jack N. Rinker, "Hyperspectral Imagery — What is it? — What can it do?," paper presented at the U.S. Army Corps of Engineers' Seventh Remote Sensing Symposium, 7-9 May 1990, Portland, Ore., p. 5.

5. Interview, author with Dr. Jack N. Rinker, Fort Belvoir, Va., 26 November 1991.

6. Dr. Jack N. Rinker, "Hyperspectral Imagery — What is it? — What can it do?," paper presented at the U.S. Army Corps of Engineers' Seventh Remote Sensing Symposium, 7-9 May 1990, Portland, Ore., p. 5.

7. Dr. Jack N. Rinker, Phyllis Corl, "Air Photo Analysis, Photo Interpretation Logic and Feature Extraction," USAETL-0329, June 1984, p. 6.

8. Rice, J.E.: Krusinger, A.E., "A New and Extensive Thermal Contrast Data Base," Proceedings — AVIRIS Specialty Group on Targets, Background Discriminations, Vol. II, 1985, pp. 1-5.

9. Dr. Jack N. Rinker, "Hyperspectral Imagery — What is it? — What can it do?," paper presented at the U.S. Army Corps of Engineers' Seventh Remote Sensing Symposium, 7-9 May 1990, Portland, Ore., p. 22.

10. Interview, author with Dr. Jack N. Rinker, Fort Belvoir, Va., 26 November 1991.

11. Interview, author with Dr. Jack N. Rinker, Fort Belvoir, Va., 26 November 1991.

12. Ibid.

13. McCauley, J.F., Breed, C.S., Helm, P.J., Billingsley, G.H., and McCauley, C.K. "Remote Monitoring of Processes That Shape Desert Surfaces: The Desert Wind Project," *U.S. Geological Survey Bulletin 1634*, 1984.

14. John F. McCauley and Dr. Jack N. Rinker, "A Workshop on Desert Processes, 24-28 September — Report on the Conference," *U.S. Geological Survey Circular 989*, p. 1.

15. Ibid.

16. Ibid, p. 5.

17. Interview, author with Dr. Jack N. Rinker, Fort Belvoir, Va., 26 November 1991.

18. *1991 Organizational Activities*, pp. 49-50.

19. *FY86 U.S. Army Laboratory of the Year Report*, p. 22.

20. *FY84 Laboratory of the Year Report*, p. 3.

21. *Tech-Tran*, Vol. 11, No. 3, Summer 1986, p. 3.

22. Ibid.

23. USAETL 1988 Annual Historical Summary, Installation Files, p. 2.

24. *1991 Organizational Activities*, p. 49.

25. Interview, author with John Benton, Fort Belvoir, Va., 14 January 1992.

26. *FY86 U.S. Army Laboratory of the Year Report*, p. 22.

27. Interview, author with John Benton, Fort Belvoir, Va., 14 January 1992.

28. Ibid.

29. Ibid.

30. "Hierarchical Route Planner," Proceedings of SPIE (International Society for Optical Engineering), Vol. 937, Application of Artificial Intelligence VI., 4-6 April 1988, pp. 428-434.

31. Ibid.

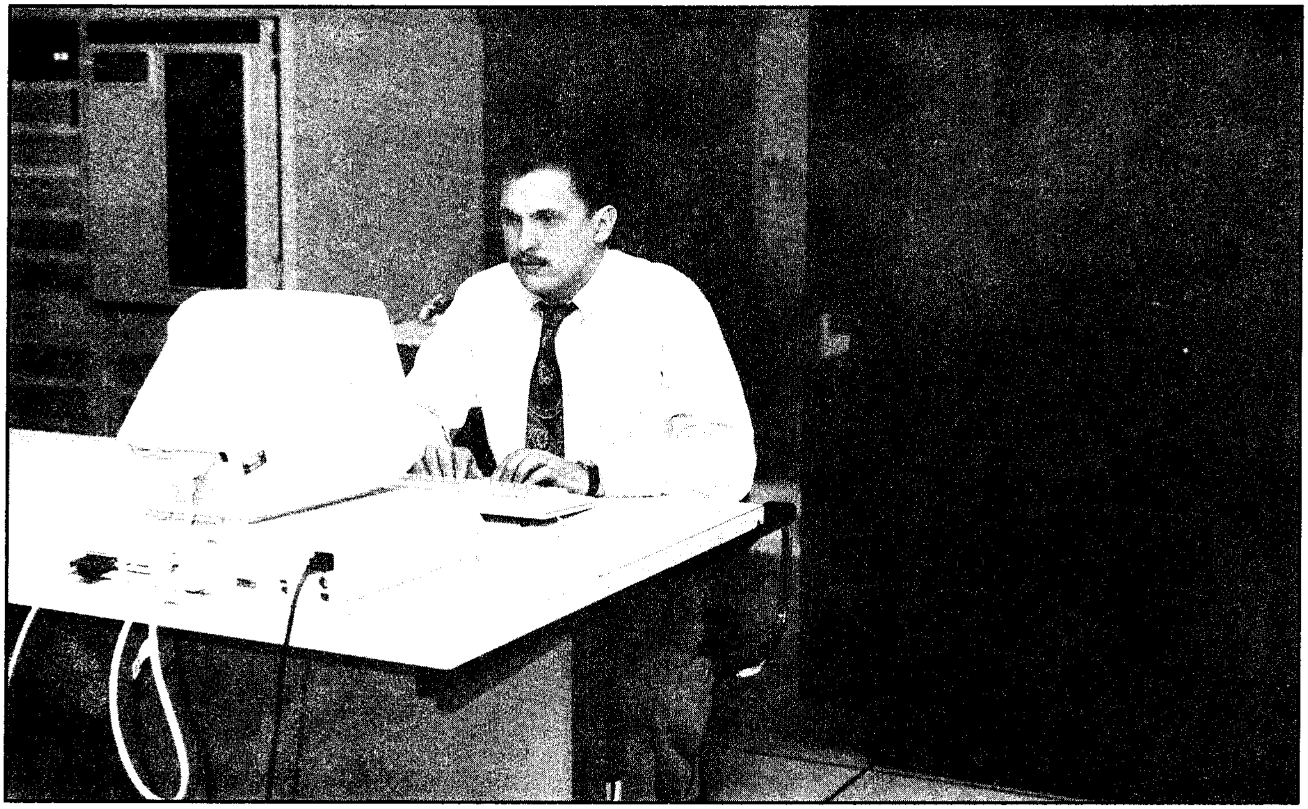
32. USAETL's 1988 Annual Historical Summary, Installation Files, p. 2.

33. Interview, author with Anne Werkheiser, Fort Belvoir, Va., 16 April 1992.

34. Interview, author with John Benton, Fort Belvoir, Va., 14 January 1992.

35. Ibid.

36. Interview, author with Anne Werkheiser, Fort Belvoir, Va., 16 April 1992.



Researcher in the Space Programs Laboratory

Space Programs Laboratory

A new element at USAETL

When the Computer Sciences Laboratory (CSL) became the Space Programs Laboratory (SPL) in 1986, it signified a new focus of USAETL research. This new orientation skyward, in turn, was mirrored by the eventual movement of many of the former CSL personnel into a new secure section of USAETL (the "Sensitive Compartmented Information Facility" or "SCIF") that increased the size of the Cude Building. The 65,000 square feet of secure space was surely needed, for USAETL was growing.

A look at USAETL's budget would show that it more than tripled during this period. Against a background of a shrinking overall military budget, this growth requires explanation. Upon reflection, it could only be explained by the extraordinary successes in the recent past, as well as some work that the Army clearly felt was well worth investing in for the future.

Unfortunately, SPL's successes were not always apparent, because a large part of the facility's work was done behind closed doors.

Birth of Space Programs Laboratory

In general, USAETL was coming to take a "broader view of the end user" of its terrain information. Military elements were getting in line for terrain information products. It was particularly hard to ignore the potential use by maneuver elements and air defense. [*FY86 U.S. Army Laboratory of the Year Report*, page 15.[1]]

USAETL scientists often pointed to the fact that there had been a revolution in the very nature of topographic, image processing and space technology applications research. This was largely due to enormous advances in electronic and computer technologies. At USAETL, where a total reorganization was underway, the time had come to restructure the laboratories to take advantage of these advances, and to arrange the infrastructure in a way that better reflected changes in both USAETL's directions of research and the identity of its customers. One of the primary changes was the creation of the SPL.

More than a name change

The birth of SPL was not merely a matter of renaming CSL. The in-house discussions on reorganizing USAETL to meet its new responsibilities had shown that the old CSL was sorely in need of an update. Already in the 1979-1983 period, USAETL's budget began to reflect a growing menu of research and development projects tied to the Army Space Program Office (ASPO). Indeed, the Digital Topographic Support System, (itself regarded as the number one candidate for additional funding to get the "Army into space" by a special U.S. Army Training and Doctrine Command task force), ranked no higher than 14th in the project priority list at the beginning of the 1984-1988 period. Most of the higher-ranked initiatives were for ASPO and most were classified.

The locus for much of this work, the old CSL, had to be wholly restructured to reflect its new focus on the varied aspects of topographic, image processing and space technology research. It was a matter of the work already being there, and the laboratory being made ready to meet the challenge more efficiently.

Three divisions formed in 1986

The resulting three completely new divisions, created in 1986, reflected SPL's focus for several years thereafter.

The **Space Concepts Division** was created to conduct exploratory development to "identify new concepts and initiatives using space and space-related resources to enhance the Army's effectiveness in carrying out its land combat mission." [*1991 Organizational Activities*.[2]] This division, in other words, would see if something "up there" could be used to help "down here."

The **Space Technology Division** was formed to develop and operate the Space Research Test-Bed Facility (SRTF). Here, USAETL researchers began to employ their test bed to conduct research and development in space-related activities.

The **Space Systems Development Division** was created to conduct some varieties of advanced and engineering development work on space-related systems.

Emerging Army space program

The purpose in creating these new divisions, and the new laboratory as a whole, was to provide a focus for those USAETL activities associated with the emerging Army space program. USAETL was pointing research and development toward helping establish a laboratory-wide Corps tech base development program. As part of this effort, SPL was to serve as head laboratory in executing the USAETL assignment to carry out a Corps-wide space program plan.

With the emergence of SPL, USAETL quickly moved to participate in a number of activities that related to the Army's growing role in space. A task force played a "proactive role" in a space technology working group established by the Deputy Chief of Staff for Research, Development and Acquisition (DCSRDA). The aim of this group was to look closely at the Army's technology base and assess its relevance to space. [*FY86 U.S. Army Laboratory of the Year Report*, page 15.[3]]

Defining a role in space

The resulting study of the DCSRDA group produced a compendium of "space-related activities within the Army, identification of generic leveraging opportunities and strategies for development of future Army plans for the exploitation for space and space-related technologies." In other words, the Army had a major role to play in space. [Ibid.[4]]

The Army Space Working Group, in turn, was operating under the Space Technology Steering and Review Committee, chaired by the DCSRDA. In an effort to coordinate Army work in this area, USAETL also participated in this committee largely made up of materiel developers. Eventually, the final report was prepared by the USAETL representatives and accepted by the rest of the committee.

Work with satellites and SDI

SPL's work did not end with its efforts to inventory and coordinate then-current Army technology. With its long experience with managing environmental data in the Geographic Sciences Laboratory (see BEES, EDGE) USAETL participated in the Army Environmental Satellite Working Group to help assure that environmental data were available to the various Army echelons in the field. As part of this effort laboratory scientists and engineers worked with the group on the Army Environmental Satellite System Operational and Organizational Plan.

Another space-related initiative had USAETL playing a major role in establishing the Army Space Research Committee (ASRC). This committee was formed to manage the Army's relationship with the Strategic Defense Initiative (SDI). The laboratories also assisted in establishing and maintaining an Army-funded integrated Space Research and Advanced Technology Base Program with the USAETL Associate Technical Director, Dr. Richard B. Gomez, serving as its executive secretary.

Dynamic knowledge of battlefield

The laboratory was directing its in-house innovations, as well as its technical projects to make full use of "space assets." This, in turn, meant finding ways to do ground data reduction of space sensor records. Through this research the laboratory was working toward a goal that had much in common with the labor of USAETL's other elements: better terrain information. But in this case, the goal was to use space-based technology to provide the tactical commander with a dynamic knowledge of the battlefield. The perspective provided from space would ideally be both more encompassing and nearer to real time.

1. EXPERIMENTS USING A MILITARY MAN IN SPACE

The years 1984-1988 saw a new focus on a program known as the "Military-Man-In-Space" (MMIS) initiatives, which were a series of efforts to put the U.S. presence in space to strategic and tactical use. At USAETL, researchers worked to support experiments into the possible merits of putting skilled human beings into space to perform either terrain analysis or imagery interpretation.

The terrain analysis experiment came to be known as TERRA GEODE and was designed to evaluate the ability of a military geologist to identify and interpret geomorphic landforms and conditions from space. The image analysis experiment, known as TERRA SCOUT, sought to determine what sort of imagery analysis might be expected from image analysts as they flew over a target. In each case, however, the aim was to ascertain if, at long last, one could "see the forest for the trees" from the vast perspective provided by a perch in space. [Interview with Richard Muniz, Fort Belvoir, Va., 12 August 1991.[5]]

A look-see from space

The idea for what SPL's Muniz called "getting a look-see from space" has been attributed to Capt. Palmer Bailey, a military geologist at the Army's Astronaut Office at the Johnson Space Flight Center. Bailey had observed a Navy mission that launched an oceanographer into space with great success, raising the possibility in Bailey's mind of doing something similar with a geologist.

After a great deal of door knocking, Bailey had his ideas in front of Lt. Gen. Elvin R. Heiberg, Chief of Engineers, on 2 October 1986. The merits of the concept moved Ray Hall with the Assistant Chief of Engineers to turn the matter into a proposal that took form on paper on 16 December 1986. The TERRA GEODE program was born.

Terrain analyst in space

SPL's Muniz, who oversaw USAETL's TERRA GEODE technical support role from the start, reflectioned on how best to employ a terrain analyst in space. [Ibid.[6]] Researchers started by informally debriefing astronauts on what they had already seen, hoping to extrapolate what might be available when the TERRA GEODE analyst finally got into space. From the astronauts' recollections, as well as from the Navy project's "tremendous discoveries" about the oceans, came a positive assessment of the possibilities. [Ibid.[7]]

What were they looking for, and what was USAETL's role in all this? Muniz cited the example of a terrain specialist using gyro-specialized binoculars, possibly to see slightly different coloring from space that might be an indicator of "soft dirt." That, in turn, might prove militarily significant for cross-country mobility and the like. USAETL's role was to provide technical support when, for example, the designers sought to marry one piece of equipment to another. SPL's software enabled Muniz and his team to predict the success and/or accuracy of such a marriage. [Ibid.[8]]

A book for space use

The research project was sent to its proponent, the U.S. Army Engineer School. There, Capt. Jim Karpiscak looked for ways to get more information from astronauts untrained in terrain analysis. In 1988, he began to put

together a book to guide an astronaut's terrain analysis judgments from space.

Astronaut Kathy Sullivan would use this terrain analysis guidebook during her "free research time" in a 24 April to 1 May 1990 ride in space. Afterward, the book was scheduled for distribution under USAETL's logo.

Space shuttle Challenger disaster

When the space shuttle Challenger blew apart, the schedule for shuttle experiments was radically disrupted. TERRA GEODE and a number of other USAETL space-related experiments were put on hold. [Ibid.[9]] Throughout this history, it is stressed that even the most abstract USAETL research was usually tied to events in some way. Following Challenger, some research shifted to a "whole different timetable." [Ibid.[10]] Since, however, USAETL's MMIS work had always been highly experimental and laboratory-based, research did not cease; indeed, it proceeded on not one, but several fronts.

2. IMAGE ANALYSIS IN SPACE

If terrain analysis could be attempted from space, it was a logical step to assume that scouting could as well. If, in Muniz's words, TERRA GEODE could allow terrain analysts to finally "see the forest for the trees," then TERRA SCOUT, by putting an image analyst in space, could allow the commander to get the ultimate overview or "big picture" of the battlefield area. There were similarities, as the projects' similar names suggested, and SPL's John Gundy labored on both. But as Gundy himself pointed out, there were key differences as well. [Interview with John Gundy, Fort Belvoir, Va., 12 August 1991.[11]]

Where TERRA GEODE had employed terrain analysis to extract features that were fairly permanent features of the terrain, TERRA SCOUT was using image analysis techniques to provide tactical information to a commander in more or less real time. The goal of this still-experimental program was to evaluate an expert image analyst's ability to perform imagery analysis as he flew over the target.

In addition to the expert analyst, the scientists of TERRA SCOUT envisioned making use of an optical aid known as the Space-borne Direct-View Optical System (SpaDVOS), a device built by Armstrong Aerospace Medical Research Laboratory in Ohio. SPL researchers helped the U.S. Army Intelligence Center and School prepare the shuttle's Payload Integration Plan, while also making sure the proper imagery was going to be available for the trainer used to simulate the SpaDVOS. Known as the Flexible Image Generation System, that simulating capability assured that once in space, the image analyst would feel at home with the equipment.

3. STAR TRACKER SHUTTLE EXPERIMENT

Another project set back, but not ended, by the Challenger disaster was an experiment to demonstrate how to determine a space platform's "attitude" with great accuracy. This idea was born of the fact that what a nonprofessional might call orientation or tilt, defies standard frames of reference in space, where even the terms "down" or "up" become problematical. A craft or platform's "attitude" remains critical, however, to make sure a device is pointed in the right direction, regardless of how that direction is measured.

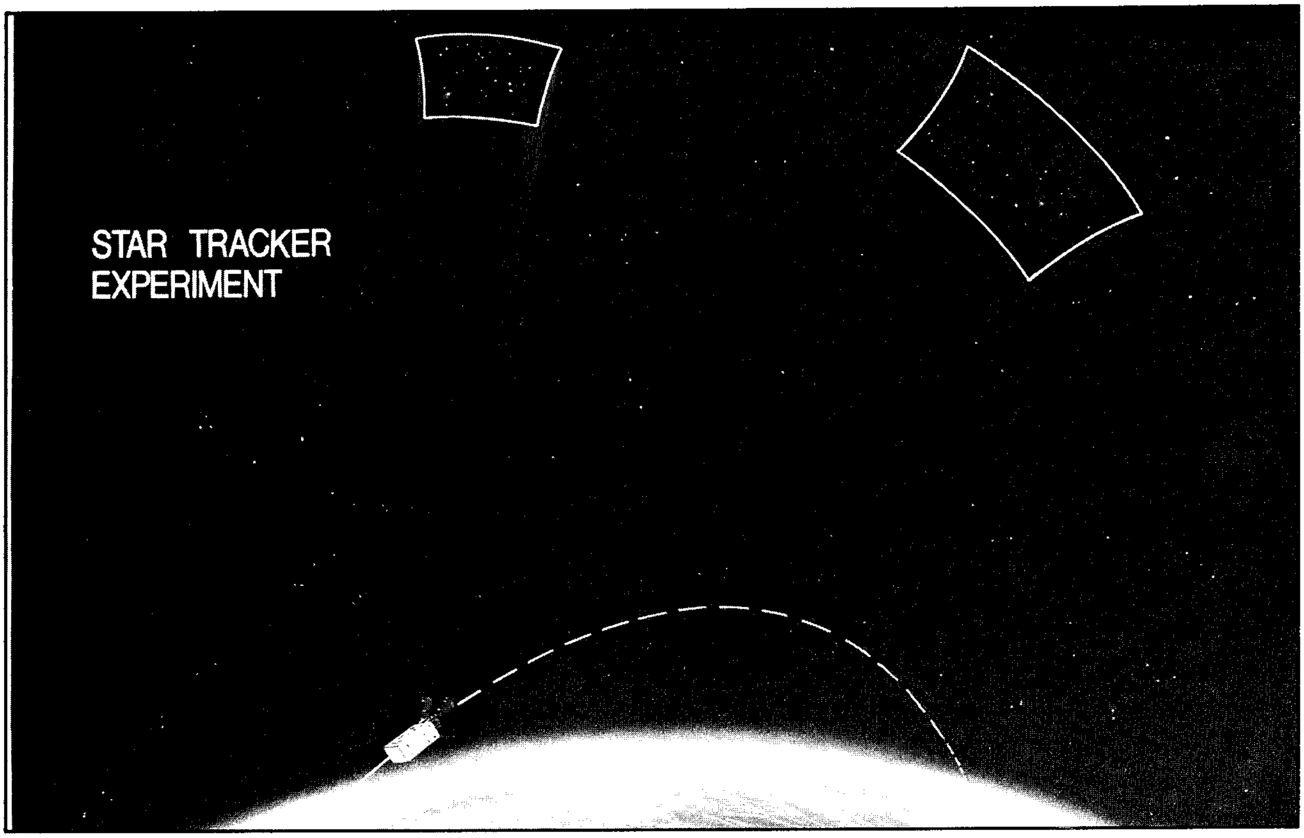
SPL scientists realized that the stars, being relatively "fixed" by human standards because they are so far away, might be used as landmarks or points of reference for attitude. In more concrete terms, this translated into designing, fabricating and integrating a digital star sensor package, "Star Tracker," for flight under the Department of Defense (DOD) Space Test Program. USAETL's experiment was so named because it sought to show the viability of using the stars to get real-time attitude readings through a solid-state star sensor. The star data were to be collected by means of a charge-coupled device (CCD) focal plane camera, supported by an onboard processor to make quick determinations of attitude. SPL's Connie Gray worked out the details of making the package ideally suited to the shuttle-based test.

Star Tracker package

Star Tracker did not lend itself readily to lay language, but a technical description is of some help. The camera was used to record light from the stars as a group of pixel points. That pixel data, in turn, arranged according to image intensity, was envisioned as providing star "image centroids" (i.e., the central point of the pixel group) on the focal plane. By storing those image centroid coordinates on magnetic tape, the system then had a record of both star magnitude and the plot of the star fields as seen within the camera's view.

The Star Tracker system would seek to turn this into a frame of reference for the spacecraft's attitude. This would be accomplished by making use of its onboard processor to compare the star fields with an onboard catalog, and then using the attitude estimated for each field to combine data into an estimated attitude that was to be stored on magnetic tape.

SPL researchers planned to do post-flight evaluation of the estimated attitude with an eye toward improving



Star Tracker experiment

the Star Tracker software, and eventually, the package's speed and accuracy. Plans also were made to have the spacecraft bring the tracker's boresight pass near the Earth, sun or moon so that SPL scientists might see how the light from these bodies would affect Star Tracker's performance.

Validating concepts and testing technology

Star Tracker may be seen as a typical project within the SPL work area where scientists were testing new technology with potential for tactical support systems involving both manned and unmanned space-borne platforms. The star sensor package, in turn, was an attempt to validate a technical concept. Finally, in the context of USAETL's history in the 1984-1988 years, it must be seen as one of the laboratories' first visible steps into space.

4. TEST BED FACILITY FOR SPACE RESEARCH

USAETL's new initiatives in space required considerable technological support. Backing up this research program was a well-integrated system of digital processing hardware, software and interactive display subsystems.

With the formation of SPL in 1986, USAETL scientists assumed the formal responsibility of putting together such a system. In the laboratory atmosphere at USAETL there was, of course, a good deal of experience to be drawn upon in setting up test beds. [*1991 Organizational Activities.*[12]] In the years 1986-1988, SPL scientists began to assemble and test the eventual components of the SRTF.

Helping the photo interpreter

The purpose of the SRTF was to support major development programs in digital image processing and space applications. Not surprisingly, the first area where SPL's researchers envisioned the facility bearing fruit was in applications functions that might help the photo interpreter. This, of course, was a very traditional focus of USAETL research.

SPL scientists looked into several promising methods to allow better photo interpretation in space-related areas. Among these were:

Image Roam — SPL researchers worked on the optimum way to view a large digital image by continually displacing a small viewed portion of the unviewed image.

Magnification — Scientists examined the merits of enlarging parts of an image to allow the analyst to better recognize details.

Filtering — SPL specialists explored ways to use "frequency domain" or "spatial domain" image processing functions. Both the former (also called Fast Fourier Transform) and the latter (Convolution) image processing functions allowed the analyst to sharpen edges or remove image degradations, thus, "filtering" out a common source of error.

Gray-Level Mapping — Here, SPL researchers simply played with the brightness and contrast of an image to aid interpretation by the analyst.

Geometric Remapping — SPL researchers investigated how the geometric alteration of an image might make an image easier to interpret.

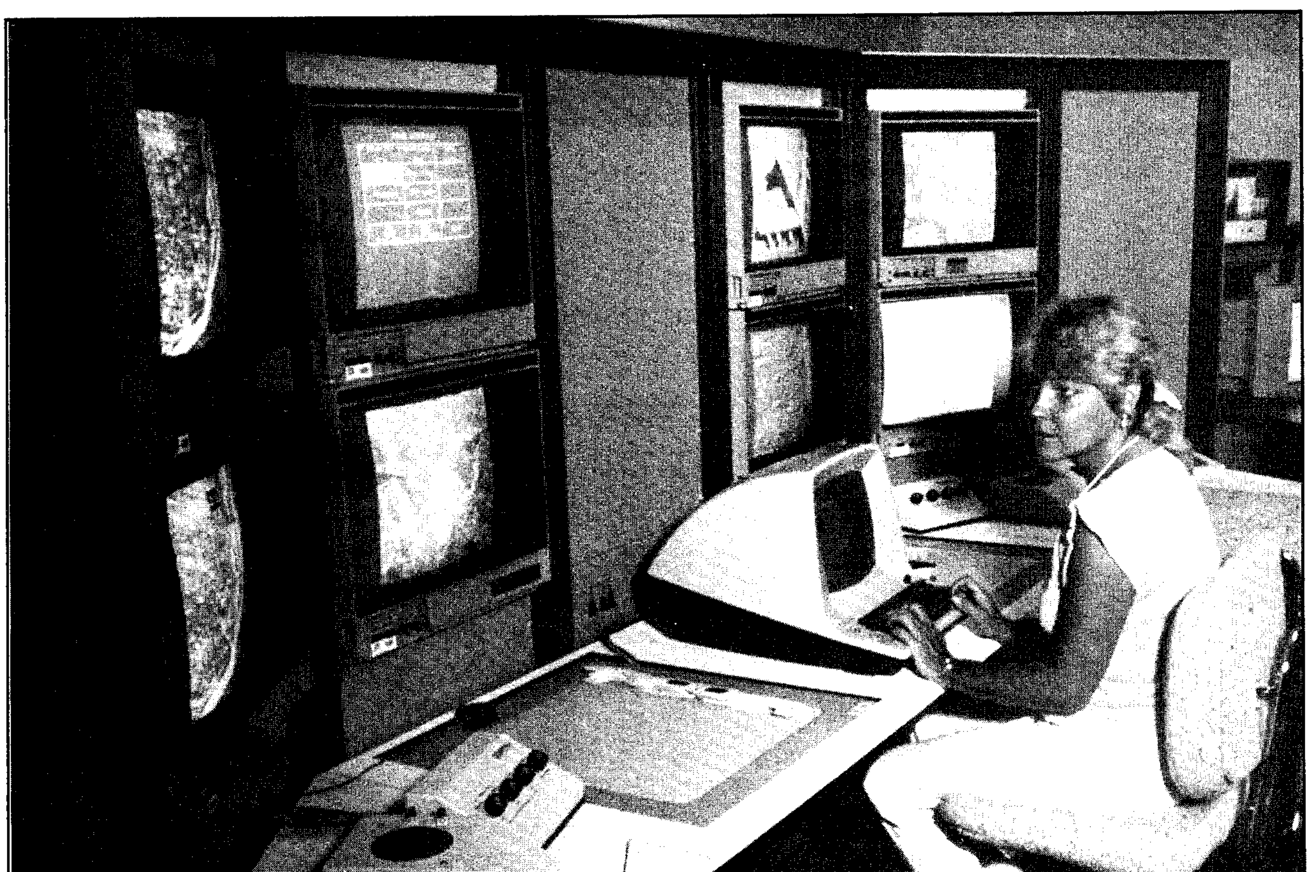
Image Annotation — The effectiveness of emphasizing particular portions of the image was studied. Specialists employed both graphic symbols and alphanumeric characters.

Multispectral Processing — In this case, the scientists operated on multiband imagery and accomplished tasks such as image classifications, change detection, scene mosaicking, registration (image and map domains), image merging and perspective views.

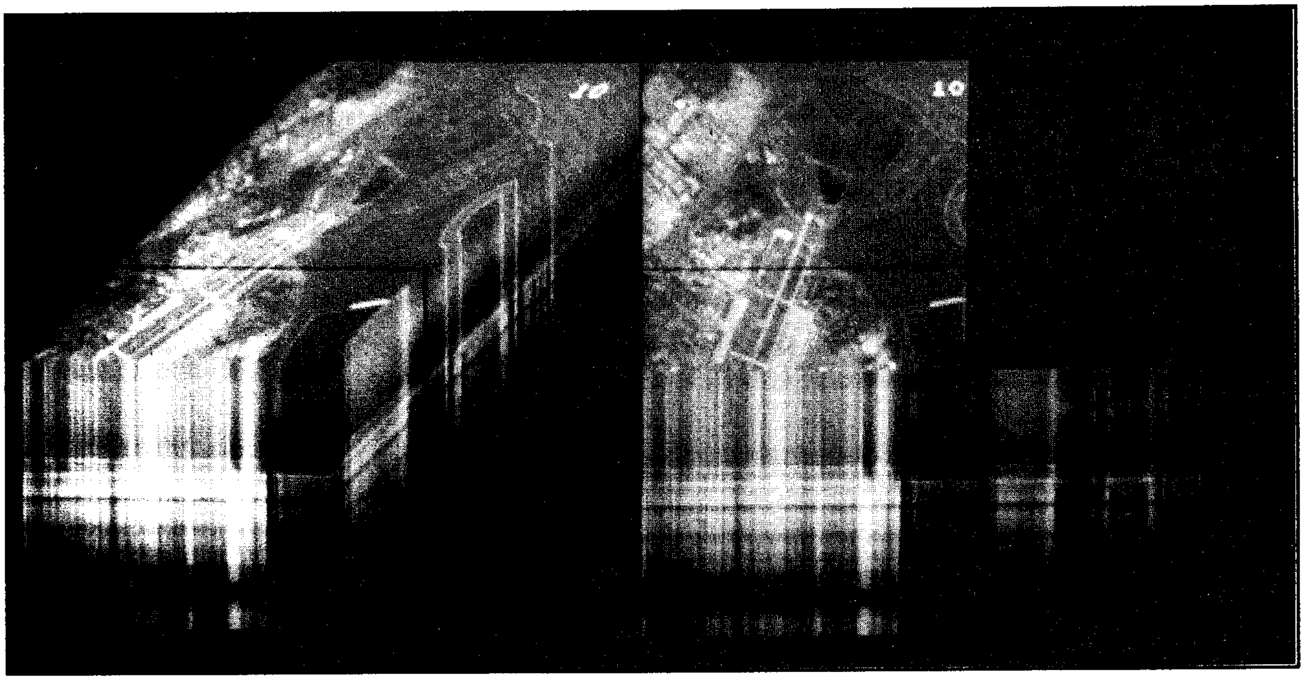
The aim of all these applications functions was the same: to assist the photo interpreter. Though a distinctly high-tech operation, the SRTF shared that goal with many long-standing USAETL initiatives.

Unique mixture of SRTF

Yet, however much the SRTF had in common with traditional USAETL areas of inquiry, SPL researchers went about their task with a unique mixture of hardware and software. The test bed evolved to include two sequential computers, two parallel computers, a specially built image processing and display station, two off-the-shelf image processors, three real-time processing and display work stations, several personal computers, a video disc system and numerous peripherals.



Space Research Test-Bed Facility



A perspective view (l) and orthographic view (r) of a hyperspectral image cube projection. The bottom shows the signature of a point feature.

5. MAKING USE OF IMAGERY FROM SATELLITES

SPL also was heavily involved in evaluating the varieties of data that the SRTF was analyzing. Accordingly, SPL undertook research into both multispectral and hyperspectral imagery. The latter was defined as involving data "gathered by imaging spectrometers operating over the .4 to 2.4 micrometer wavelength region of the electromagnetic spectrum and producing 128 or more images (bands) over this wavelength interval." [Ibid.[13]] SPL's Donald Davis, however, said the line between the two varieties of imagery was not clearly drawn in these years. A more obvious distinction was that multispectral data were, in fact, incoming from Landsat sensors, while hyperspectral data were not.

The different approaches could be envisioned as analogous to experimenting with different lenses to see which enables an onlooker to "see" more clearly. Here, however, there were no lenses involved, but rather sensors, and the issue was one of information rather than clarity. SPL researchers were pursuing the much more arcane matter of what wavelength intervals should constitute an image channel (band) on the imaging spectrometer, and what image exploitation techniques best made use of the data. Was it multispectral imagery that used less bands, and looking to "classify" what was being extracted into categories of all that matched up; or was it hyperspectral imagery, employing many more bands, and seeking to actually "identify" what it sensed? This was a major riddle in these years, and solving it was a task that SPL shared with the remote sensing specialists in USAETL's Research Institute (RI).

Hyperspectral studies

Throughout the 1984-1988 period, Robert Rand, Samuel Barr and other SPL researchers examined a form of imagery processing that was not yet satellite-based. These "hyperspectral" studies involved collecting test data from airplanes, helicopters etc., equipped with hyperspectral sensors, mostly at the Jet Propulsion Laboratory. In so doing, they also made use of spectrometer data of natural features and man-made objects of interest collected by RI and other agencies.

The resulting data were readied for testing on USAETL's SRTF. SPL researchers directed their analysis and experimentation toward finding out what might be the best sort of hyperspectral sensor for Army purposes. Making this determination required "resolving a host of tough research issues." [Interview with Donald Davis, Fort Belvoir, Va., 19 August 1991.[14]]

Hyperspectral sensor for Army

Because, in James Stilwell's words, hyperspectral techniques "slice up the visible/IR spectrum in more bands," it remained for SPL scientists to "strike a balance in working out which ones were wanted." [Interview with James Stilwell, Fort Belvoir, Va., 23 August 1991.[15]] This was an issue in part because "only so much data could be stored and sent." [Ibid.[16]] For that reason, research also relied on the kind of data reduction

techniques required to allow the Army to exploit hyperspectral data for terrain and image intelligence. SPL's Barry Holecheck, for example, worked on an image cube as a way of better visualizing multiple bands.

SPL scientists kept the focus of hyperspectral studies on who the eventual users would be and what products they would require. [Ibid.[17]] In general, this resulted in work designed to match wavelength curves in the hope of identifying features, and some attempts to achieve "atmospheric backout," i.e., to compensate for atmospheric distortion in hyperspectral sensors. But the overriding goal was to one day raise the level of image spectrometry to where "identification" of imagery supplemented mere classification. The belief that this would be done soon was not, however, shared by everyone.

Bulky but promising package

Researcher Stilwell referred to the hyperspectral package as a "bulky one" and cautioned that the research in the 1984-1988 years did not yet solve a number of problems.

Why, then, the hyperspectral initiatives? Stilwell cited the immense promise of actually being able to identify things in this new type of imagery. For all the problems with storage, etc., the hyperspectral research had to be pursued in order to keep USAETL at the leading edge in providing the Army with a powerful image exploitation capability. In the interest of maintaining that edge, plans were made to study the latest hyperspectral sensors just then becoming available to the remote sensing community. Barr undertook a study of the Airborne Visible and Infrared Imaging Spectrometer (AVIRIS) which promised approximately 10 times the spectral resolution of the current Landsat data. Barr planned a study of hyperspectral image data, including supportive studies on the spectral properties of target material backgrounds, while Holecheck examined appropriate computer processing techniques. The promise of hyperspectral sensing was too great to be left to some undefined future. Even RI's Dr. Jack Rinker, a skeptic when it came to automating feature extraction, saw immense promise for hyperspectral scanning for targeting.

Multispectral studies for satellite use

Well before the 1984-1988 period, USAETL researchers were aware that imagery from the U.S. Landsat satellite system might have potential uses for the Army. It had been routinely used since the 1970s in such fields as geography, geology, forestry, agriculture, hydrology and cartography. Unfortunately, the limited resolution of the original Multispectral Scanner (MSS) imagery had not shown itself suited to military applications.

The breakthrough came in 1983, however, when the Landsat Thematic Mapper (TM) sensor was made available. The change from a 4-band to a 7-band scanner was "the big step forward." It also helped when commercial satellite imagery from France and Japan came on-line later.

Resumed multispectral studies in 1982

Scientists at USAETL resumed studying the uses of Landsat data in 1982, just before the TM came into use. Researchers saw that possibilities were emerging for "unsupervised classification" of matched-up features by means of satellite sensors.

The initial research involved comparing the accuracy of land-cover information secured from the old multispectral scanner with that of the new thematic mapper and seeing if these data sources might make up a more realistic perspective view of the earth's surface when merged with Defense Mapping Agency's (DMA) Digital Terrain Elevation Data. Some work began at northern Georgia test sites where scientists gathered multispectral scanner, thematic mapper, and both DMA digital elevation and digital features data.

Tests in Georgia and subsequent study

The tests in Georgia were made to compare the accuracy of the data from the two satellite sensors with Digital Feature Analysis Data from DMA — a known quantity. The Landsat land-cover information obtained from the TM showed well in the tests, exhibiting a great deal of potential.

USAETL researchers generated three-dimensional perspective views by combining the remotely sensed information with digital elevation data. Laboratory scientists then set up these scenes to give the viewer the impression of "flying through" the data. The researchers put together software to allow the users to select a vantage point, vertically exaggerate features, and add haze and other environmental effects.

SPL research even had a role in the digital elevation data part of the story as well. SPL's F. Raye Norvelle had done some major upgrading work on DMA's UNAMACE (Universal Automatic Map Compilation Equipment) at the start of this period. For restructuring the software to allow doubling the compilation speed, Norvelle was awarded DMA's Research and Development Award in June 1987.

ADRIES

From 1986, USAETL provided "critical technical, managerial and administrative support to the Advanced Digital Radar Imagery Exploitation System (ADRIES) Program." [*FY86 U.S. Army Laboratory of the Year Report*, page 29.[18]] This program combined hardware from the Defense Advanced Research Projects Agency's Strategic Computing Program (SCP) with knowledge-based expert system developments to demonstrate a system for automated exploitation of Synthetic Aperture Radar data. ADRIES research focused on exploiting technology in the fields of signal and image processing, image understanding and decision analysis systems.

The ADRIES concept was the "first time an integrated end-to-end intelligent processing capability" had been demonstrated where "terrain information and spatial military deployments patterns had been used in answering an exploitation requirement." [USAETL 1988 Annual Historical Summary, Installation Files, page 2.[19]] This also was one of the first application efforts under the SCP. This resulted in the award of a Balanced Technology Initiative (BTI) for demonstrating a field prototype capability for automated imagery exploitation. [Ibid.[20]]

ADRIES was related to other initiatives undertaken for ASPO. In 1988, SPL installed a device within the Demonstration System/Digital Imagery Test Bed and the Echelon Above Corps Test Bed to permit dissemination to systems with similar devices that had been installed in Army Technical Exploitation of National Capabilities (TENCAP) systems. A contract was awarded for field modifications of the two aforementioned test beds.

In 1986, the Advanced Synthetic Aperture Radar Systems (ASARS) Interface Device under ASPO was completed successfully and deployed to Europe. [*FY86 U.S. Army Laboratory of the Year Report*, page v.[21]] In 1988, SPL specialists further modified the device to provide high-resolution radar imagery to Army headquarters in Europe, the U.S. Army Intelligence Center and School, and other Army and DOD users.

Footnotes

1. *FY86 U.S. Army Laboratory of the Year Report*, p. 15.

2. *1991 Organizational Activities.*

3. *FY86 U.S. Army Laboratory of the Year Report*, p. 15.

4. Ibid.

5. Interview, author with Richard Muniz, Fort Belvoir, Va., 12 August 1991.

6. Ibid.

7. Ibid.

8. Ibid.

9. Ibid.

10. Ibid.

11. Interview, author with John Gundy, Fort Belvoir, Va., 12 August 1991.

12. *1991 Organizational Activities.*

13. Ibid.

14. Interview, author with Donald Davis, Fort Belvoir, Va., 19 August 1991.

15. Interview, author with James Stilwell, Fort Belvoir, Va., 23 August 1991.

16. Ibid.

17. Ibid.

18. *FY86 U.S. Army Laboratory of the Year Report*, p. 29.

19. USAETL 1988 Annual Historical Summary, Installation Files, p. 2.

20. Ibid.

21. *FY86 U.S. Army Laboratory of the Year Report*, p. v.

Acronyms

ACP	Army Country Profiles
ADDSFAC	Army Digital Data Support Facility
ADRG	ARC-Digitized Raster Graphics
ADRIES	Advanced Digital Radar Imagery Exploitation System
AI	Artificial Intelligence
AIS	Army Intelligence Survey
ALBE	AirLand Battlefield Environment
ALV	Autonomous Land Vehicle
AMC	U.S. Army Materiel Command
APPS	Analytical Photogrammetric Positioning System
ARTBASS	Army Training Battlefield Simulation System
ARTINS	Army Terrain Information System
ASARS	Advanced Synthetic Aperture Radar Systems
AS	Acquisition Strategy
ASAS	All-Source Analysis System
ASPO	Army Space Program Office
ASRC	Army Space Research Committee
ASTRO	Army Space Technology Research Office
ASTWG	Army Space Technology Working Group
ATD	Autonomous Technologies Division
AVHRR	Airborne Very-High Resolution Radiometer
AVIRIS	Airborne Visible and Infrared Imaging Spectrometer
BEES	Battlefield Environmental Effects Software
BIC	Battlefield-Induced Contaminants
BTI	Balanced Technology Initiative
CAD	Concepts and Analysis Division (USAETL)
CAI	Center for Artificial Intelligence (USAETL)
CAMMS	Condensed Army Mobility Modeling System
CAPIR	Computer-Assisted Photo Interpretation Research
CCD	Charge-Coupled Device
CECOM	U.S. Army Communications — Electronics Command
CIG	Computer Image Generation
CRS	Center for Remote Sensing (USAETL)
CSL	Computer Sciences Laboratory (USAETL)
DARPA	Defense Advanced Research Projects Agency
DCAC	Digital Concepts and Analysis Center (USAETL)
DCSLOG	Deputy Chief of Staff for Logistics
DCSRDA	Deputy Chief of Staff for Research, Development and Acquisition
DEMONS	Demonstration System
DFAD	Digital Feature Analysis Data
DIA	Defense Intelligence Agency
DMA	Defense Mapping Agency
DOD	Department of Defense
DRU	Dynamic Reference Unit
DTAS	Digital Terrain Analysis Station

DTD	Digital Topographic Data
DTED	Digital Terrain Elevation Data
DTSS	Digital Topographic Support System
DX	Highest Defense Priority Designation
EDGE	Environmental Design Guidance for Evaluation
EEB	Environmenatl Effects Branch
EMD	Electronic Map Data
ERADCOM	Electronics Research and Development Command
ERDAS	Earth Resources Data Analysis System
FDA	U.S. Food and Drug Administration
FEED	Field Exploitation of Elevation Data
FGCC	Federal Geodetic Control Committee
FORSCOM	U.S. Forces Command
FSED	Full-Scale Engineering Development
GSL	Geographic Sciences Laboratory
GIS	Geographic Information System
GPS	Global Positioning System
HRP	Hierarchical Route Planner
IMS	Integrated Meteorological System
IPB	Intelligence Preparation of the Battlefield
IPS	Inertial Positioning System
ITAC	U.S. Army Intelligence and Threat Analysis Center
ITD	Interim Terrain Data
JSTARS	Joint Surveillance and Target Attack Radar System
JTFPMO	Joint Tactical Fusion Program Management Office
LMS	Light Mensuration System
MAPS	Modular Azimuth Position System
MCS	Maneuver Control System
MGI	Military Geographic Information
MICOM	U.S. Army Missile Command
MMIS	Military Man In Space
MSS	Multispectral Scanner
NAD27	North American Datum of 1927
NAD83	North American Datum of 1983
NAVSTAR	NAVSTAR
NBC	Nuclear, Biological and Chemical
NGS	National Geodetic Survey
NOAA	National Oceanic and Atmospheric Administration
PADS	Position and Azimuth Determining System
PII	Pershing II Guidance Missile
PM	Program Manager or Project Manager
QRMP	Quick Response Multicolor Printer
R&D	Research and Development
RGSS	Rapid Geodetic Survey System
RI	Research Institute (USAETL)
ROC	Required Operational Capability
RPC	Regional Preparedness Committee

RSGF	Reference Scene Generation Facility
SCIF	Sensitive Compartmented Information Facility
SCP	Strategic Computing Program
SDI	Strategic Defense Initiative
SIMNET	Simulation Network
SPL	Space Programs Laboratory (USAETL)
SpaDVOS	Space-borne Direct-View Optical System
SPR	Statistical Pattern Recognition
SRTF	Space Research Test-Bed Facility
STD	Special Terrain Data
TAC	Terrain Analysis Center (USAETL)
TACOM	U.S. Army Tank-Automotive Command
TAD	Terrain Analysis Demonstrator
TAWS	Terrain Analyst Work Station
TDA	Tactical Decision Aid
TDL	Topographic Developments Laboratory (USAETL)
TEC	U.S. Army Topographic Engineering Center
TENCAP	Technical Exploitation of National Capabilities
TERCOM	Tomahawk's Terrain Contour Matching
TIES	Terrain Information Extraction System
TIMS	Thermal Infrared Multispectral Scanner
TISG	Terrain Information Systems Group
TM	Thematic Mapper
TRAC	Tactical Radar Correlator
TROSCOM	U.S. Army Troop Support Command
TSS	Topographic Support System
TTD	Tactical Terrain Data
TVTB	Terrain Visualization Test Bed
UIES	USAREUR Imagery Exploitation System
UNAMACE	Universal Automatic Map Compilation Equipment
USAETL	U.S. Army Engineer Topographic Laboratories
USAREUR	U.S. Army Europe
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WAMS	Wetlands Analytical Mapping System (Fish and Wildlife Service)
WDRT	Water Detection Response Team
WES	U.S. Army Engineer Waterways Experiment Station
WRDB	Water Resources Data Base

Organizational Charts, 1984-1988

The multitude of laboratories, divisions and work groups at the U.S. Army Engineering Topographic Laboratories (USAETL) makes tracking institutional changes challenging. The nature of laboratory research and development assures that changes will be many; so many that listing them all would fill this volume to the exclusion of everything else. The author has chosen instead to mention the most significant changes, and to include this information in the course of treating the work itself. For further classification purposes, however, the following dated organizational charts of USAETL are provided.

U.S. ARMY
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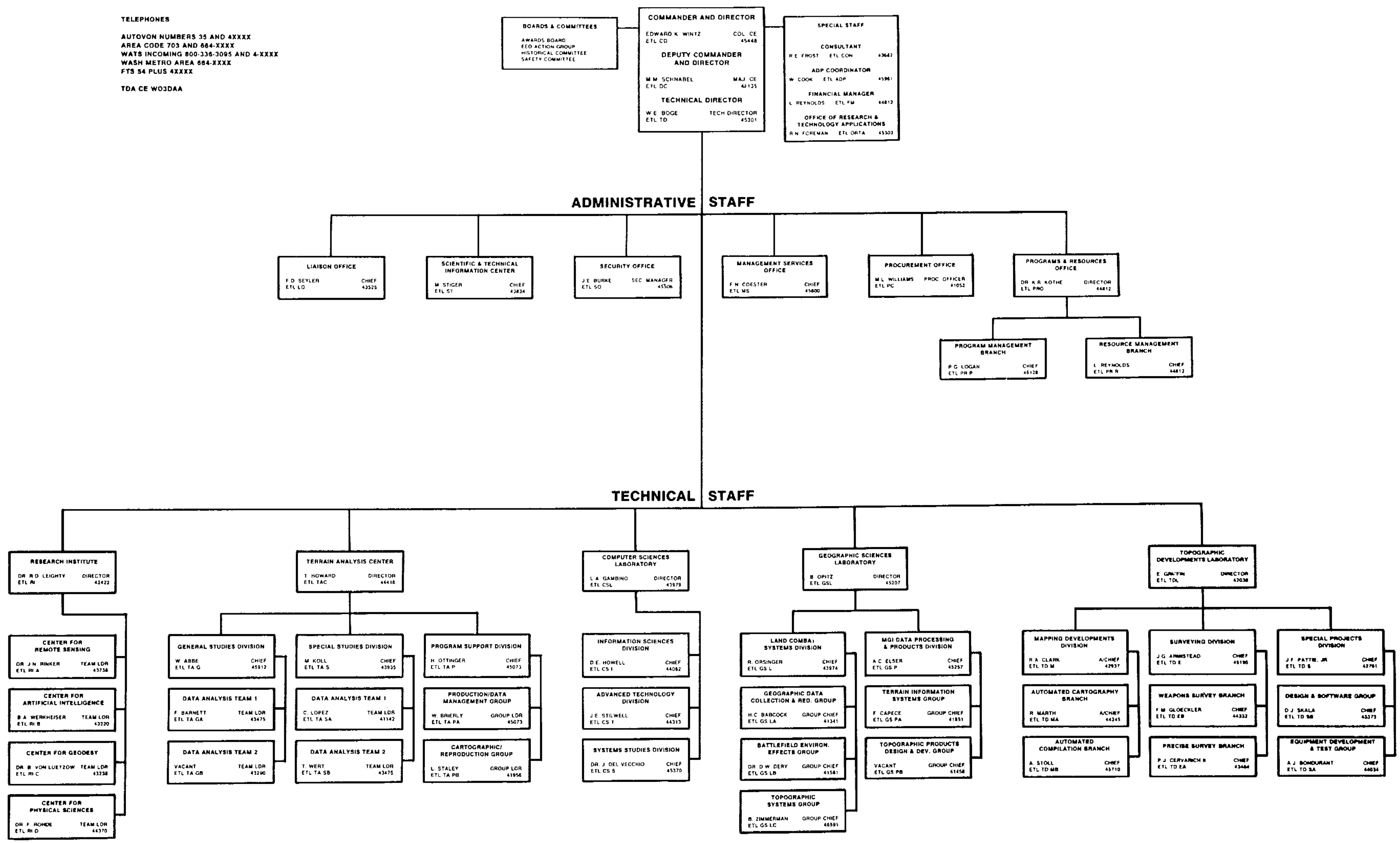

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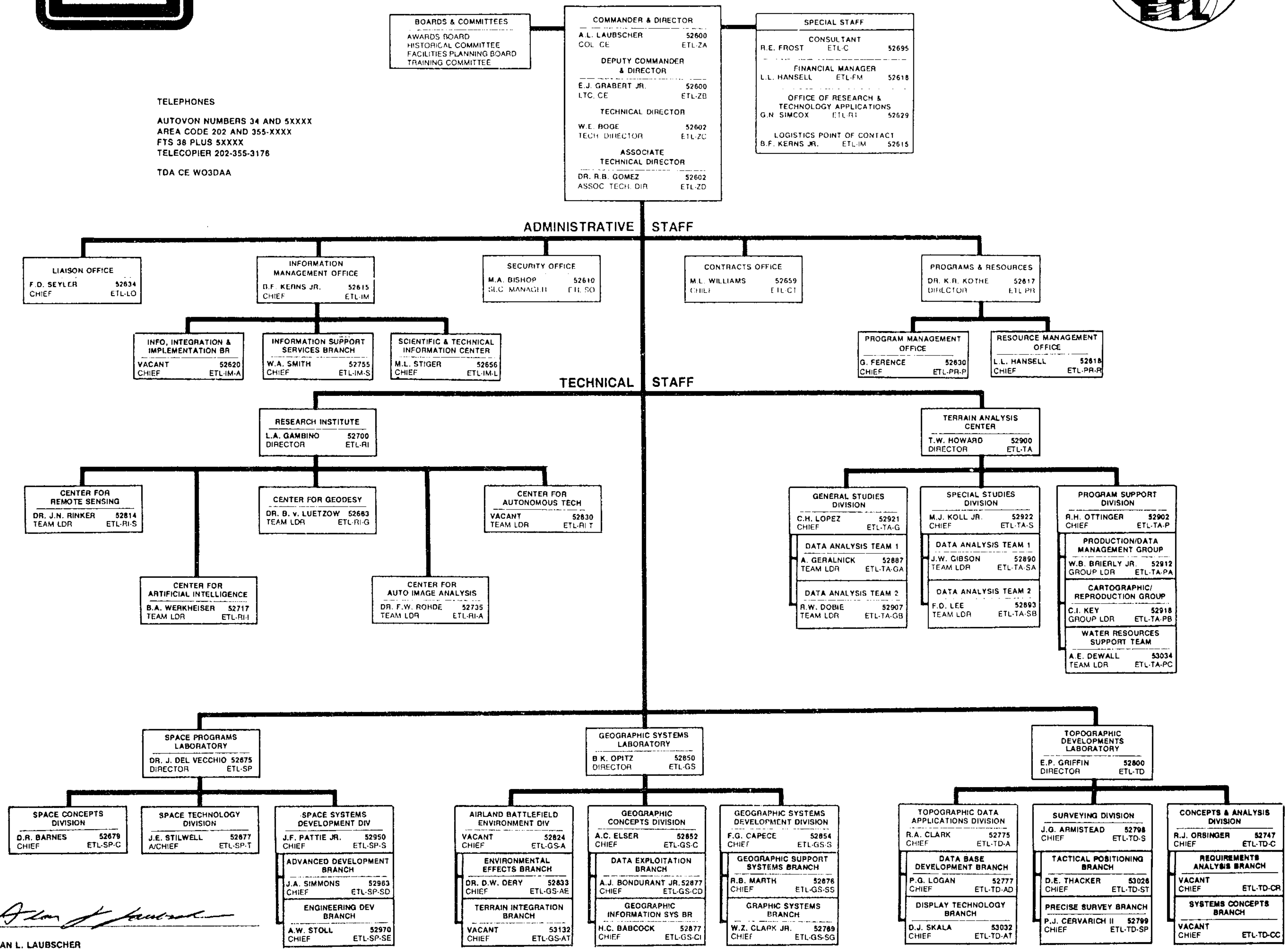

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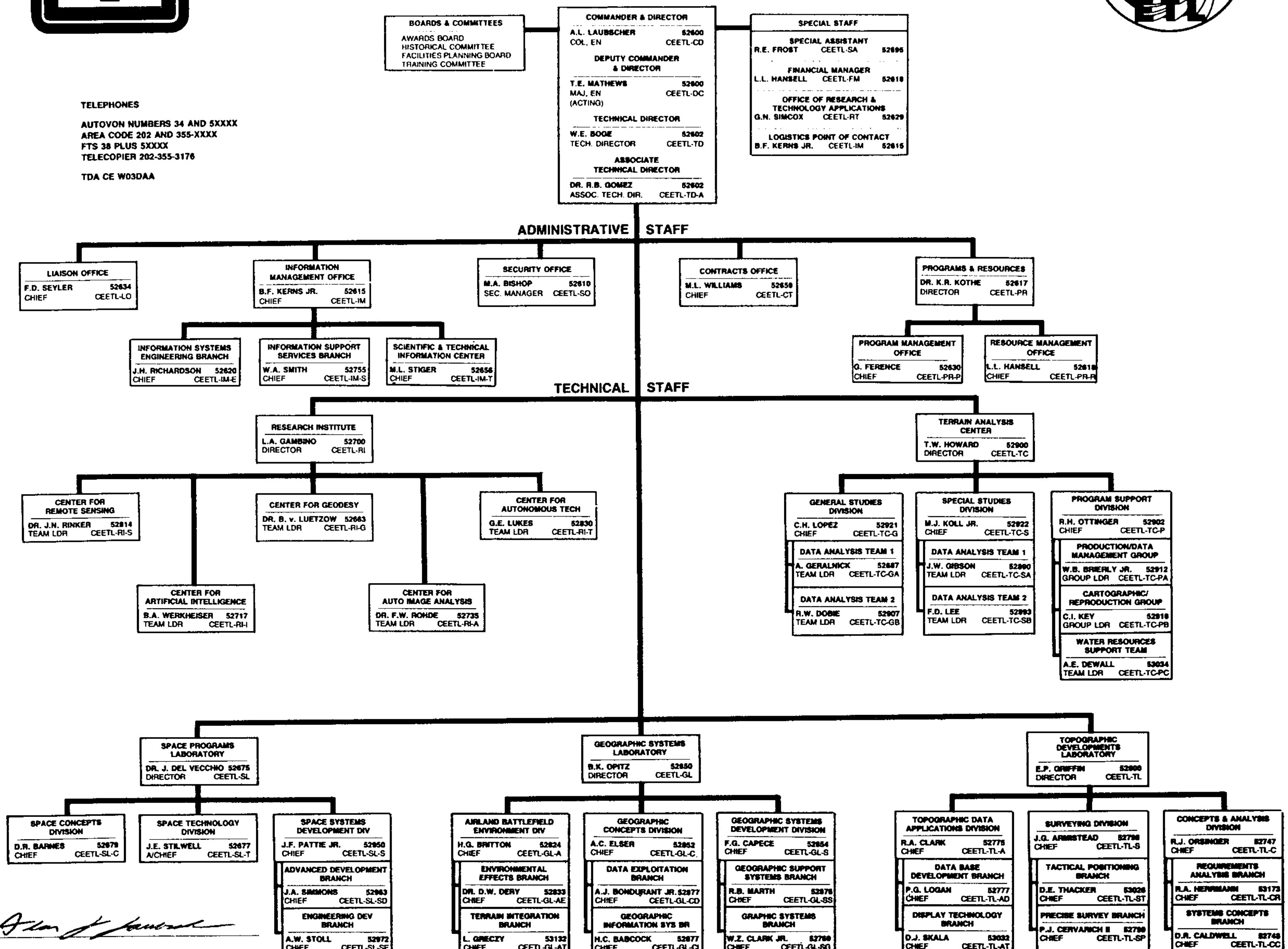

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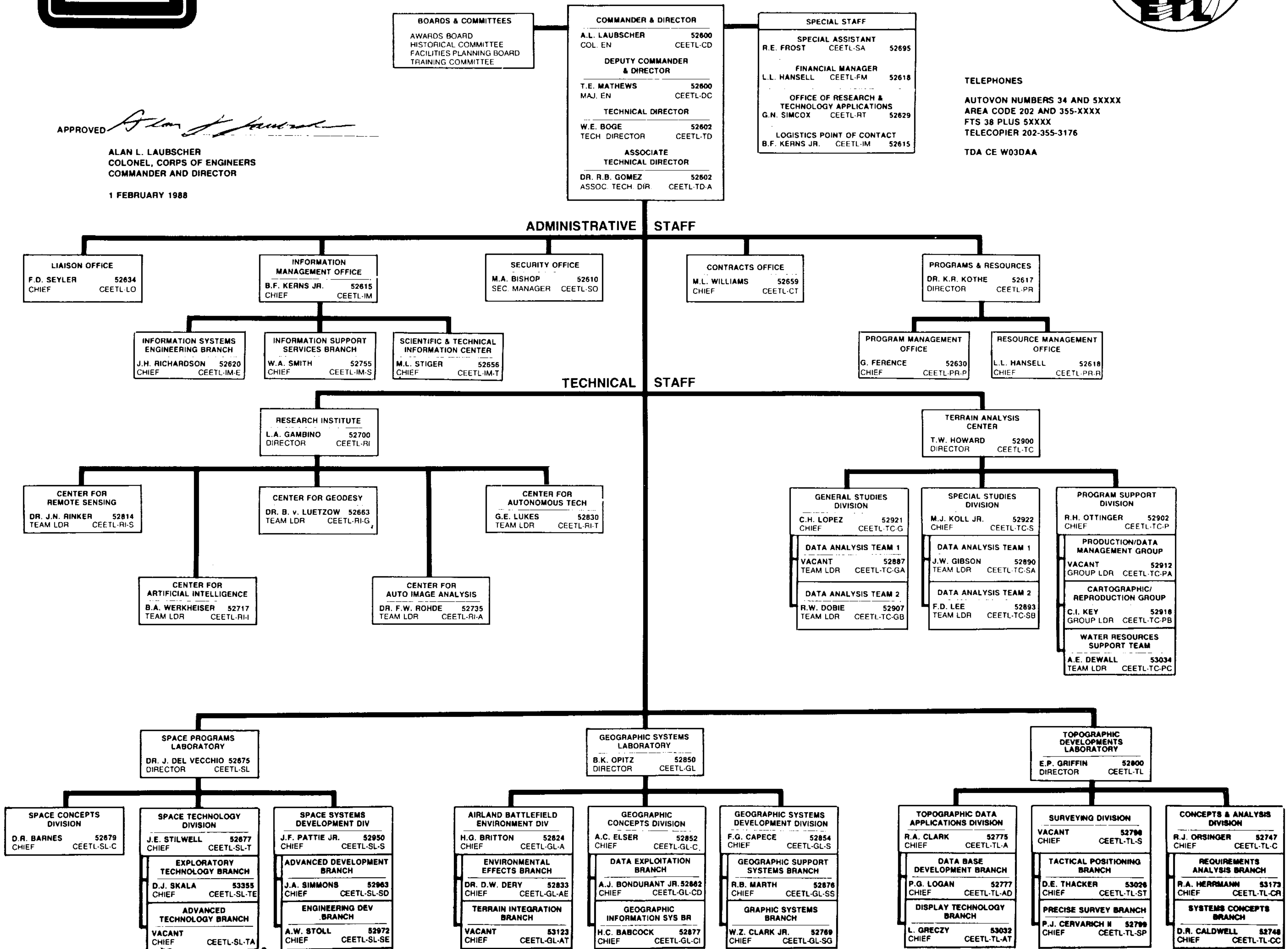

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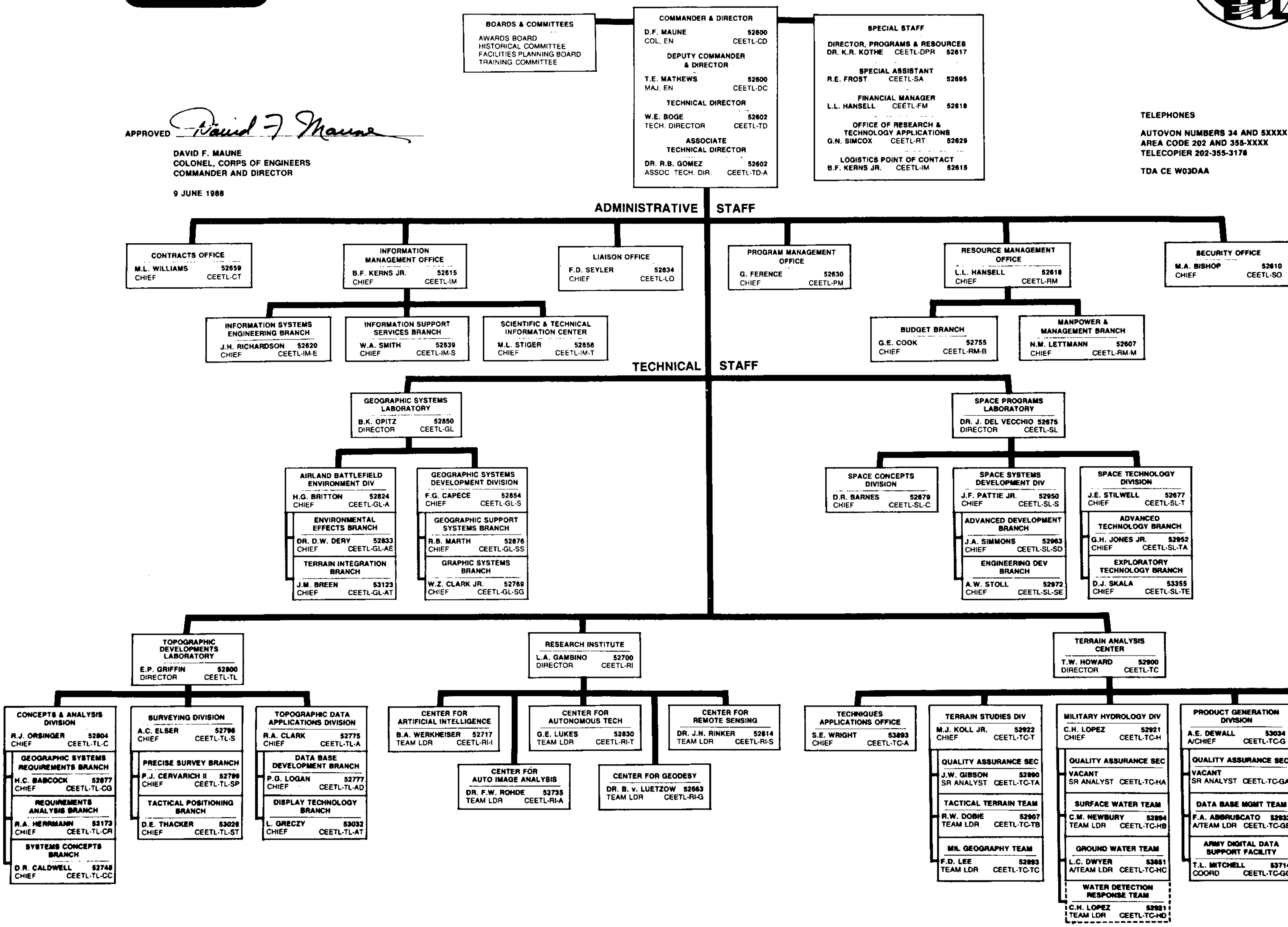

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Bibliography

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Background

ALBE: The AirLand Battlefield Environment, Office of the Chief of Engineers, U.S. Army, Fort Belvoir, Va., 1984.

Army Digital Topographic Data Requirements, (ETL SR-4), Fort Belvoir, Va., August 1984.

Army Tactical Digital Terrain Data Requirements Forecast (FY87-FY93), (ETL-SR-1), Fort Belvoir, Va., July 1987.

Headquarters, Department of the Army, Washington, D.C., "Army Topography," Army Regulation No. 115-11, 1 March 1980.

Bagrow, Leo, and Skelton, R.A., *History of Cartography,* Cambridge, Mass., Harvard University Press, 1984.

Burkhard, Capt. R.K., *Geodesy for the Layman,* St. Louis, Mo., Aeronautic Chart Information Center, 1968.

Carr, W. Howard, "Cartography Automation, Yesterday, Today, Tomorrow," paper presented to the American Congress on Surveying and Mapping, and American Society of Photogrammetry, Salt Lake City, Utah, 19-23 September 1983.

Durkin, Maj. Gen. Robert, "Charting a World of All-Digital Maps," *Defense,* 1988, pp. 21-25.

Ezell, Dr. Edward C., *ETL History Update, 1968-1978,* U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Va., February 1979.

Hamilton, Andrew, and Hellman, Robert, *A History Update of the U.S. Army Engineer Topographic Laboratories, 1979-1983,* U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Va., 1985.

Laubscher, Col. Alan E., "An Open Letter to former Commander and Director, Col. Edward K. Wintz (Ret.)," *Lab Lines* (September/October 1986), p. 2.

Leighty, Dr. Robert D., "Trends in Automated Analysis of Aerial Imagery," paper presented to the 22nd Meeting of the ARO Electronics Coordinating Group, Pingree Park, Colo., 6-9 September 1983.

Lukes, George E., "CAPIR Computer-Assisted Photo Interpretation Research," paper presented to the 17th International Symposium on Remote Sensing on the Environment, Ann Arbor, Mich., 9-13 May 1983.

Pennington, John T., *History of U.S. Army Engineer Topographic Laboratories, 1920-1970,* U.S. Army Engineer Topographic Laboratories, ETL-SR-74-1, Fort Belvoir, Va., November 1973.

Topographic Developments Laboratory

Burkard, Capt. R.K., *Geodesy for the Layman* St. Louis: Aeronautical Chart Information Center, 1968.

Durkin, Maj. Gen. Robert, "Charting a World of All-Digital Maps," *Defense*, 1988, pp. 20-25.

DeLoach, Stephen R., "Continuous Deformation Monitoring with GPS," paper presented at the 11-14 May 1988, American Society of Civil Engineers' Specialty Conference, "*GPS 88-Engineering Applications of GPS Satellite Surveying Technology*," p. 93.

Digital Data Digest, Vol. 1, No. 3 (Winter 1991).

Gallay, Capt. David, *Tech-Tran*, Vol. 6, No. 3 (Summer 1981).

Herrmann, Richard, briefings on DCAC, Fort Belvoir, Va., 11 January 1991; 26 January 1991.

Maune, Col. David F., "TEC to support simulation systems and programs for DTD Exploitation," *Digital Data Digest*, Vol. 2, No. 1 (Fall 1991).

U.S. Army Laboratory of the Year Reports, Installation Files.

USAETL Annual Historical Summaries, Installation Files.

Interviews:

Cervarich, Peter, interview, Fort Belvoir, Va., 5 February 1992.

DeLoach, Stephen R., interview, Fort Belvoir, Va., 6 May 1991.

Gloeckler, Frederick, interview, Fort Belvoir, Va., 12 January 1985.

Marth, Richard, interview, Fort Belvoir, Va., 17 April 1991.

Perrin, Jack, interview, Fort Belvoir, Va., 28 May 1986.

Robertson, Kenneth, interview, Fort Belvoir, Va., 3 October 1984.

Orsinger, Regis, interview, Fort Belvoir, Va., 1 July 1991.

Simcox, George, interviews, Fort Belvoir, Va., 1 January 1990; 3 March 1990.

Stoll, Anthony, interview, Fort Belvoir, Va., 17 May 1991.

Geographic Sciences Laboratory

Aitken, George W., *AirLand Battlefield Environment Overview*, Installation Files, unpaginated.

Army Environmental Sciences, Vol. 8, No. 2 (Fall 1989).

Army Regulation 70-38, *Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions.*

Army Research and Development Organization of the Year Report for FY88, Installation Files.

DTSS Historical Facts, in-house document, Installation Files, 17 October 1990.

Kurtz, Keith, *Memorandum to TDL Director*, Fort Belvoir, Va., 19 May 1992.

Greczy, Laslo, *AirLand Battlefield Environment (ALBE) Demonstration*, Installation Files, unpaginated.

Mandel, Betty, *ALBE Provides Tactical Advantage*, Installation Files, unpaginated.

"QRMP," in-house document, Installation Files, unpaginated.

U.S. Army Laboratory of the Year Reports, Installation Files.

Interviews:

Capece, Frank, interview, Fort Belvoir, Va., 14 October 1984.

Caldwell, Douglas, interview, Fort Belvoir, Va., 22 May 1991.

Desmond, Gregory, interview, Fort Belvoir, Va., 5 February 1992.

Edwards, Daniel, interview, Fort Belvoir, Va., 2 July 1991.

Greczy, Laslo, interview, Fort Belvoir, Va., 16 January 1992.

Kothe, Dr. Kenneth, interview, Fort Belvoir, Va., 11 October 1984.

Krause, Paul, interviews, Fort Belvoir, Va., 24 October 1984, 5 February 1985.

Logan, Paul, interview, Fort Belvoir, Va., 5 February 1992.

Marth, Richard, interview, Fort Belvoir, Va., 17 May 1991.

Orsinger, Regis, interview, Fort Belvoir, Va., 1 July 1991.

Terrain Analysis Center

Army Research and Development Organization of the Year Report for FY88 (document known in previous years as the *U.S. Army Laboratory of the Year Report).*

"Command Groups Train with Army Simulation System," *Tech-Tran*, Vol. 12, No. 2 (Fall 1987).

DeWall, Allan E., unpublished draft of Water Detection Response Team release, Installation Files, unpaginated.

DeWall, Allan E., Baehr, John N., and Dwyer, Laura C., Memorandum for the Record, Installation Files, 2 April 1985.

Durkin, Maj. Gen. Robert, "Charting a World of All-Digital Maps," *Defense*, 1988, pp. 20-25.

Howard, Theodore W., briefing on TAC, Fort Belvoir, Va., 17 January 1991.

Newbury, Claudia, *Terrain Analysis Center Modernization Plan*, U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Va., September 1987.

"QRMP," in-house document, Installation Files, unpaginated.

U.S. Army Laboratory of the Year Reports, Installation Files.

USAETL Annual Historical Summaries, Installation Files.

Interviews:

DeWall, Allan E., interview, Fort Belvoir, Va., 5 June 1992.

Dobie, Richard W., interview, Fort Belvoir, Va., 15 May 1991.

Howard, Theodore W., interviews, Fort Belvoir, Va., 11 October 1984; 24 May 1991; 5 June 1992.

Koll, Jack, interview, Fort Belvoir, Va., 17 January 1990.

Research Institute

Benton, John, "Hierarchical Route Planner," Proceedings of SPIE (International Society for Optical Engineering), Vol. 937, Application of Artificial Intelligence VI., 4-6 April 1988, pp. 428-434.

"DARPA Envisions New Generation of Machine Intelligent Technology," *Aviation Week and Space Technology*, Vol. 4, 22 April 1983, pp. 46-54.

Leighty, Dr. Robert D., "Merging Remote Sensing and Mapping Techniques for Building Terrain Data Bases," paper presented to the Corps of Engineers IV Remote Sensing Symposium, Reston, Va., 7-9 November 1983.

McCauley, John F., and Rinker, Dr. Jack N., "A Workshop on Desert Processes, 24-28 September — Report on the Conference," *U.S. Geological Survey Circular 989*.

McCauley, J.F., Breed, C.S., Helm, P.J., Billingsley, G.H., and. McCauley, C.K., "Remote Monitoring of Processes That Shape Desert Surfaces: The Desert Wind Project," *U.S. Geological Survey Bulletin 1634*, 1984.

1991 Organizational Activities, in-house document, Installation Files, pp. 49-50.

Rice, J.E., and Krusinger, A.E., "A New and Extensive Thermal Contrast Data Base," Proceedings — AVIRIS Specialty Group on Targets, Background Discriminations, Vol. II, 1985.

Rinker, Dr. Jack N., "Hyperspectral Imagery — What is it? — What can it do?," paper presented at the U.S. Army Corps of Engineers' VII Remote Sensing Symposium, 7-9 May 1990, Portland, Ore.

Rinker, Dr. Jack N., and Corl, Phyllis, "Air Photo Analysis, Photo Interpretation Logic and Feature Extraction," USAETL-0329, June 1984.

Tech-Tran, Vol. 11, No. 3 (Summer 1986).

U.S. Army Laboratory of the Year Reports, Installation Files.

USAETL Annual Historical Summaries, Installation Files.

Interviews:

Benton, John, interview, Fort Belvoir, Va., 14 January 1992.

Krusinger, Alan, interview, Fort Belvoir, Va., 26 March 1985.

Maune, Col. David F., interview, Fort Belvoir, Va., 4 November 1991.

Rinker, Dr. Jack N., interviews, Fort Belvoir, Va., 20 September 1984; 26 November 1991.

Werkheiser, Anne, interview, Fort Belvoir, Va., 16 April 1992.

Space Programs Laboratory

U.S. Army Laboratory of the Year Reports, Installation Files.

USAETL Annual Historical Summaries, Installation Files.

Interviews:

Davis, Donald , interview, Fort Belvoir, Va., 19 August 1991.

Gundy, John, interview, Fort Belvoir, Va., 12 August 1991.

Muniz, Richard, interview, Fort Belvoir, Va., 12 August 1991.

Stilwell, James, interview, Fort Belvoir, Va., 23 August, 1991.

*Previous Histories of the U.S. Army Engineer Topographic Laboratories

Report ETL-SR-74 History of U.S. Army Engineer Topographic Laboratories, (1920 to 1970), John T. Pennington, November 1973

ETL History Update 1968-1978, Dr. Edward C. Ezell, February 1979

A History Update of the U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Virginia 1979-1983

ETL-SR-74-1 (Supplement 1) Impact of the USAETL Field Office and Its Predecessors on Military Mapping Research and Development, Robert G. Livingston, Summer 1992

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